Conservation Plan

for the

Southern Watershed Area

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Conservation Plan for the Southern Watershed Area

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For:

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EXECUTIVE SUMMARY

The Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR), at the request of the Hampton Roads Planning District Commission, has prepared a Conservation Plan to serve as one component of the Southern Watershed Area Management Program (SWAMP). SWAMP is a collaborative management effort seeking to protect and enhance the natural resources, sensitive lands, and water supplies of the Southern Watersheds Area (SWA) of Chesapeake and Virginia Beach while maintaining a balance with economic development opportunities. This Conservation Plan is intended to provide a science-based foundation for conserving the area's biological resources and integrates with three other SWAMP components: an Agriculture Plan, a Multiple Benefits Conservation Plan, and a Rural Area Preservation Plan. The sections of the plan are briefly summarized below.

Planning for Conservation. The Plan discusses the growing body of knowledge that now clearly demonstrates the social and economic benefits of retaining intact natural ecosystems and open-space as integrated components of human communities. The benefits or *ecosystem services* that such non-developed areas provide are real, substantial, and increasingly measurable. However, since these benefits are not well-recognized through traditional economic valuation, they are often not weighed against the more tangible values of economic development (money and jobs). Thus, they are frequently overlooked, undervalued, or ignored.

Scattered, unconnected natural areas representing remnants of once-continuous natural habitats have limited potential to provide diverse ecosystem services. One alternative that allows growing human communities and natural systems to coexist is to provide connections between remnant patches of habitat by means of a system of linear open spaces called *conservation corridors*. Corridors and greenways restore some of the previous landscape connectivity, providing habitat connections for wide-ranging animals as well as the gene flow necessary to maintain healthy, viable populations of plants and animals. In addition to providing wildlife habitat connections and protecting ecosystems, conservation corridors have been used to promote and enhance local parks, recreational, and educational interests

Ecosystem Description and **Natural Resources.** The Conservation Plan identifies the most significant biological resources that remain in the SWA and describes adjacent land and water, as well as natural processes that support them. The three watersheds of the SWA – Northwest River, North Landing River, and Back Bay – represent the northern extent of the Albemarle–Pamlico Estuary. This area is uniquely located both at the northern range limit for many southern species and at the southern range limit for many northern species. Because of this merging of southern and northern affinities, biodiversity of the SWA is remarkable. Extensive wetlands of the SWA have helped to protect the region's natural resources from rapid development patterns so evident just northward. As a result, the SWA supports 19 rare natural communities plus 67 plant and 22 animal species rare to Virginia.

DCR identifies *conservation sites,* defined as areas of land that support occurrences of rare plants and animals plus exemplary natural communities. These rare species and their habitats are in turn defined as *natural heritage resources*. Conservation sites contain both natural heritage resources and the lands and waters necessary to maintain natural processes critical to these resources. Conservation site boundaries are drawn primarily to reflect habitat requirements and ecological, not political or property boundaries. Because these boundaries are based primarily on ecosystem-level processes, conservation sites are optimal units upon which to base conservation and resource management plans. Sites are also specifically designed to protect natural heritage resources, which are often highly

sensitive to disturbance caused by human land use and development. Thus, conservation sites are often effective indicators of relatively intact and functional natural ecosystems, incorporating an array of natural resources and physical features – common as well as rare. Conservation sites therefore represent a rough minimum area necessary to protect existing natural biodiversity. Detailed descriptions of conservation sites that form the core of the SWA's priority conservation lands are appended to this Summary; the sites are depicted in Figure 3.

Development of Conservation Corridors. Conservation corridors provide connectivity for wildlife (and people) between primary natural habitats that otherwise become isolated by unplanned land use development patterns. Designating conservation corridors in advance of a fast-developing urban landscape is a proactive approach for retaining natural landscape connectivity, natural resources, and other open-space benefits. Corridors situated in already developed areas have great potential for restoring open-space and landscape level ecosystem functions. A system of conservation corridors will sustain natural communities and populations of native plants and animals while also providing a multitude of values to Chesapeake and Virginia Beach, including:

- protection of riparian systems;
- improved surface and ground water quality;
- reduced air and noise pollution
- recreational opportunities such as wildlife-watching, canoeing, kayaking, hunting and fishing where appropriate, walking, hiking, and bicycling;
- natural history, natural resource conservation, and biological educational opportunities;
- enhanced property values;
- improved quality of life.

This Plan presents a set of options for landscape level conservation corridor placement suggesting increasing levels of natural resource conservation. Options are based on various combinations of (1) currently protected lands, (2) known conservation sites, and (3) additional conservation corridor lands. Five options are presented in a series of maps (*Figures 6 - 12*) that display proposed landscape visions varying considerably in extent, ranging from the status quo up to a high level of open-space protection.

The *Low Corridor Density Option* represents the status quo and is comprised of the current acreage of public and private protected lands in the SWA (38,523 acres; 15.8% of the total SWA). The *Moderate-Low Corridor Density Option* includes both currently protected lands plus those linear areas that connect them – up to a width of one-half mile (50,249 acres; 20.7%). The *Medium Corridor Density Option* augments the simple corridor system defined in the previous option with additional currently unprotected conservation sites from the SWA (94,853 acres; 39.0%). The *Moderate-High Corridor Density Option* includes all existing but currently unprotected conservation sites on both public and private lands, plus half-mile wide corridors forming a network of connected conservation lands (98,480 acres; 40.5%). Finally, the *High Corridor Density Option* includes all currently protected conservation lands, all conservation sites, corridor lands connecting these areas, and additional conservation corridors that increase landscape connectivity and allow large-scale ecosystem processes to remain functional (108,909 acres; 44.8%). Much of the land area in the three higher corridor density options includes currently developed land uses. These areas could be designated as potential conservation lands and restored to open-space such as ball fields, managed forests, and agricultural lands as opportunities arise over a long time span (decades).

Much of this land area would be designated as future open-space and include currently developed land uses that would be restored over time. Figure 11 depicts this conservation corridor density with selected land uses in the SWA. Private property rights considerations should be paramount in any

implementation strategies, since most lands designated within corridors are privately owned. Fee simple purchase, conservation easements, purchase of development rights, or agricultural reserve programs are effective methods by which fair compensation can be made. Extensive areas are already in some state of development, while others are undergoing land-use alterations. Many (if not most) areas within corridors would require hydrologic and vegetative restoration representing many opportunities for mitigation.

Within conservation corridors a variety of land uses, in addition to protection of ecosystem services, are possible. These include both private and public uses, such as:

- Public recreation – hunting, fishing, hiking, biking, canoeing, wildlife viewing
- Agriculture
- Forestry
- Low intensity, low impact residential, commercial, or industrial development
- Natural history education

Stewardship of Corridor Habitats. Conservation planners recognize that appropriate land management practices are necessary to protect, support, or restore ecological processes that sustain the biodiversity of natural areas and provide optimum natural resource benefits to people. Corridor areas will present heightened stewardship challenges because they are so closely integrated into the context of human development, and because restoration of altered habitats is much more difficult than maintenance of existing natural habitat.

The Conservation Plan discusses key stewardship issues relating to the development and maintenance of conservation corridors. These include:

- water quality monitoring
- public use
- prescribed fire
- hydrologic restoration
- invasive species control
- restoring natural vegetation/communities
- habitat creation
- forest management
- habitat restoration
- mitigation banks
- wildlife management

Protection Methods. The Plan outlines a variety of land protection tools and approaches that are available to facilitate the protection of natural areas and open-space for areas not already in some class of protected status. Methods can be tailored to different conservation needs and specific landowner situations and include voluntary protection and management agreements, purchase of development rights, open space and conservation easements, and fee simple acquisition. A wide variety of funding sources and programs, including grants and financial incentive programs, exist which could potentially fund efforts towards conservation, protection, restoration, habitat enhancement, and other initiatives.

Protection Priorities. In 1989, DCR and The Nature Conservancy began protection efforts that to date, have resulted in the acquisition of 20 tracts on the North Landing River and six on the Northwest River. Additional tracts owned by the U.S. Army Corps of Engineers, the City of Chesapeake, the City of Virginia Beach, Virginia Department of Game and Inland Fisheries, and the U.S. Fish and Wildlife Service add to the lands along these rivers and Back Bay receiving at least

some level of environmental protection. Protection of individual tracts containing significant elements of biodiversity is a good first step toward conservation of critical habitats in the region; however, ecosystem-level conservation requires an approach that emphasizes linkage of natural areas and the viability of conservation sites within a larger landscape context. This plan prioritizes conservation sites and adjacent lands to facilitate immediate (near-term) protection, restoration, mitigation, and conservation efforts (Figure 13). Identification of these lands does not imply that other sites or lands are unimportant, but rather that these areas are critically important to meeting goals of the SWAMP. Prioritization of sites was based upon assessment of: site location, size, contribution to SWAMP goals, management needs, vulnerability to immediate or long-term threats, and ecological significance.

Summary and Recommendations. Communities across the country are grappling with growth and lessons of unplanned urban expansion are evident around us. The Cities of Chesapeake and Virginia Beach are fortunate to have such a remarkable assemblage of relatively-intact biological and natural resources, and are wise to work proactively to retain and enhance their open space, water quality, wildlife habitat, and biological diversity. The use of conservation corridors represents only part of an integrated ecosystem and natural resource protection strategy that will require the concerted effort of a variety of local, state, and federal agencies, both public and private. But the foundation of an effective conservation program should be a vision for a future landscape that successfully expresses the views and wishes of local residents, businesses, and government entities. Successfully managing growth means empowering citizens and leaders to make informed decisions about whether or not it is important and desirable to conserve open space and natural resources.

This Conservation Plan is one part of a multi-faceted planning effort being undertaken through the SWAMP program. Its intended role is to serve as underpinning on which to base conservation choices and as a fabric into which other planning components can be integrated. Protecting and managing conservation corridors will yield natural resource benefits to the community, and should also serve the long-term economic and quality-of-life needs of the citizens of Chesapeake and Virginia Beach.

INTRODUCTION

The cities of Chesapeake and Virginia Beach in conjunction with the Virginia Coastal Program and the Hampton Roads Planning District Commission (HRPDC) are collaborating on the Southern Watershed Area Management Program (SWAMP). The mission of SWAMP is to protect and enhance natural resources, sensitive lands, and water supplies by developing a cooperative planning and management effort for the Southern Watershed Area (SWA). The SWA encompasses portions of the Northwest River, North Landing River, and Back Bay watersheds and covers approximately 325 square miles (Figure 1).

The goals of SWAMP are to:

1) protect and enhance water quality;
2) preserve open lands;
3) ensure the compatibility of recreational activities and commerce with natural resource protection;
4) preserve the rural character of the southern watersheds while providing for residential development;
5) sustain and encourage agricultural and forestal activities in the SWA.

In early 2000, the Virginia Department of Conservation and Recreation's Division of Natural Heritage (DCR-DNH) began work on this Conservation Plan which is intended to integrate with three other concurrently-developed SWAMP plans: Strategic Plan for Agriculture, Multiple Benefits Conservation Plan, and Rural Area Preservation Plan. The Conservation Plan identifies key lands that support the natural resource base and focuses on the remaining key habitats for rare species of plants and animals plus outstanding examples of native forest and marsh communities. The Plan provides a rationale and suggests options for linking these lands using the concept of *conservation corridors*, and outlines strategies to protect and sustain natural resources and processes that are integral to long-term ecosystem health. If such strategies are carried out, quality of life for the future citizens of Chesapeake and Virginia Beach will be enhanced by the planned retention of values that arise from functioning open-space, healthy forests, wetlands, and natural areas.

Values and benefits provided by open or "green" space are too often missing in localities that have allowed unchecked sprawl to design the landscape. Identification of long-term conservation goals and implementation of an effective conservation strategy to retain an adequate and desirable natural resource base is a critical goal of this plan and SWAMP as a whole.

PLANNING FOR CONSERVATION: A LITERATURE REVIEW

Planning for conservation, addressing conservation issues, and protecting land for open space help to assure the economic future of a community and increases the quality of life for its citizens (Brabec 1992; Daily *et al.* 2000; Lindsey and Knaap 1999; Scott *et al.* 1998). In the SWA of southeastern Virginia, remaining forested wetlands and agricultural lands are rapidly being replaced with residential housing, commercial and industrial development, roads, and other developed land uses – a pattern typical of areas with rapid population growth rates. From 1970 to 1990, the human population of the SWA increased 280% (HRPDC 2001). During the 1990's, the population of Chesapeake and Virginia Beach increased by 29.6% and 7.1%, respectively (Weldon Cooper Center 2000). The necessity for economic development in urban areas is not at question – expanding population centers require vibrant business growth and suitable infrastructure. However, elimination of forests, wetlands, and open spaces bordering neighborhoods and within communities results in tremendous loss of values and benefits to people and represents a terrible sacrifice and diminished quality of life.

The value of open space has in the past been taken for granted by society and its loss considered a requisite trade-off for "progress" and economic development. However, there is current evidence that citizens of rapidly growing communities have become more aware of the positive aspects of retaining open space and containing sprawl (City of Raleigh 2000; Richmond Times-Dispatch 2000). Such changing societal views make it possible for local governments to design mechanisms to plan and manage urban expansion in order to retain natural landscape features.

Natural ecosystems provide functions that support life - not just plants and animals of forests and marshes, but also human life. These functions have been called *ecosystem services* (Daily *et al.* 2000; Dixon and Sherman 1990; Holden and Ehrlich 1974; Kirby 1993). Examples of *ecosystem services* provided by natural habitats and open space follow:

- purification of air and water;
- mitigation of droughts and floods;
- genesis, preservation, and renewal of soils;
- detoxification and decomposition of wastes;
- pollination of crops and natural vegetation;
- dispersal of seeds;
- cycling and movement of nutrients;
- control of the vast majority of potential agricultural pests;
- maintenance of biodiversity by providing habitat for native species of plants and animals;
- protection of coastal shorelines from wave erosion;
- protection to humans from sun's ultraviolet rays;
- recreational opportunities;
- natural history education / outdoor classrooms;
- biological research opportunities;
- moderation of weather extremes and their impacts;
- provision of aesthetic beauty and intellectual stimulation that lifts the human spirit.

Benefits derived from these *services* provided by natural ecosystems have been undervalued by society. They are not traded in formal markets and so do not send price signals that warn of changes in supply or condition. Relatively few people are even conscious of the role natural *services* play in generating those ecosystem goods that *are* traded in the marketplace, such as agricultural and forest products. Placing a value on natural ecosystems, like valuing human life, is fraught with difficulties (Daily *et al.* 2000; Fausold and Lilieholm 1999; Scott *et al.* 1998). However, in order to avoid permanent loss of benefits and values, it is wise to establish fundamental ecosystem safeguards even when uncertainty over economic value remains. Numerous human-caused threats to natural ecosystems exist, including exotic species introductions, extinction of species, ground and surface water flow alterations, and habitat loss through infrastructure development (roads, buildings, rights-of-way, etc.). These changes are difficult or expensive to reverse on time scales relevant to people. With 3 million acres of open space disappearing in the United States each year (Biondo 2000), and with most remaining natural systems damaged and fragmented, it is critical that efforts be made *now* to protect and conserve open space, natural habitats, and functioning ecosystems.

The difficulty of expressing ecosystem values in traditional terms has given rise to several new ways of analyzing value and evaluating less tangible concepts. One of the new sciences devoted to this process is *contingent valuation methodology* (CVM). CVM applies benefit transfer principles, functions and services of the ecosystem, *travel cost methodology*, and *hedonic damage pricing* and arrives at an economic 'value,' or estimation of the value of ecosystem services and other public goods (Kirby 1993; Lindsey and Knaap 1999; Scott *et al.* 1998). This value is then used by planners,

figure 1

researchers, and economists for planning and budgetary purposes. Another method used by researchers attempting to quantify the 'value of ecosystem services' is to measure *willingness to pay* (WTP) by local residents. To establish this, researchers interview and poll communities regarding a variety of topics ranging from such broad concepts as "nature conservation," to more specific issues such as wetlands preservation, salmon re-stocking, and mosquito control (Lindsey and Knaap 1999; Pate and Loomis 1997; White and Lovett 1999). Researchers have discovered that WTP is directly linked to geographic distance, and to a small degree, to the specific program or service (Fausold and Lilieholm 1999; Gresswell and Liss 1995; Lindsey and Knaap 1999; Pate and Loomis 1997; White and Lovett 1999). Lindsey and Knaap (1999) found that "…there are indeed public benefits to private landscapes, but that in any particular place, their value depends on salience and proximity to individuals, as well as other site-specific characteristics…" WTP can be used as a tangible measure of how important or valuable these things are to people.

Some economic values of open space and ecotourism are easily quantified. Proximity to open spaces (greenways, wildland corridors, and natural areas) is often touted in real estate advertisements as factors that increase the worth of property. These values have been called "enhancement value" and "livability" of an area (Fausold and Lilieholm 1999). A large body of information documents the success and enhanced value of residential development located near open spaces (Adams and Mundy 1991; Brabec 1992; Fausold and Lilieholm 1999; Vicary 1994). This enhancement value is explicitly recognized by federal income tax law - U.S. Treasury regulation Section 14(h)(3)(1). For example, Section 14(h)(4) cites an example of a landowner with ten one-acre plots who donates a conservation easement on eight of these lots: "By perpetually restricting development on this portion of the land, [the landowner] has ensured that the two remaining acres will always be bordered by parkland, thus increasing their fair market value," (Small 1990). In short, numerous studies suggest that pa rks and open sp ace have positive impacts on neighboring property values (Brabec 1992; Lindsey and Knaap 1999; Weicher and Zeibst 1973).

Recreational fishing and hunting generate approximately $70 billion dollars a year in the United States (USDI 1996). In the SWA, these activities are extremely popular attracting hunters and fishermen from around the state as well as the surrounding region. Certainly, healthy natural ecosystems are important for maintaining wildlife-dependent activities and the various service and retail industries they support.

Ecotourism and birdwatching are two of the fastest growing recreational pursuits in the U.S. and both depend on healthy ecosystems supported by intact natural processes and open space. The rise in popularity of these pastimes has recently supported increased associated business activity contributing millions of dollars to many local economies (Lindberg 1996; Kerlinger 1993; Wiedner and Kerlinger 1990). Nationwide, birders annually contributed between $20 and $30 billion to the economy during the 1990's (Kerlinger 1993). In Virginia's SWA, ecotourism and birdwatching have likewise increased dramatically during the last decade. Numbers of birders are increasing in part because people are living longer and retiring with sufficient resources to travel extensively. A growing popular interest in observing and studying other wildlife such as reptiles, amphibians, butterflies, as well as plants helps support economic endeavors such as canoe liveries and "bed and breakfasts." Healthy natural ecosystems offer substantial promise for expanded businesses, *e.g*. whale-watching trips, sea kayaking, and other forms of nature-based tourism (Bergstrom *et al*. 1990; Kirby 1993).

Maintaining and improving water quality for public water supplies and recreational use is an ecosystem-level management issue of great importance in the SWA. Intact natural systems are key to protecting water quality. Many of the Best Management Practices (BMPs) currently promoted to protect water quality are actually strategies for protecting or restoring the natural filtering processes of natural systems. Recent research has helped to establish standards for riparian buffer width needed

to protect surface water from sources of point and non-point pollution (Lowrance *et al.* 1997). New studies are being conducted, and others are needed to determine protection needs for groundwater recharge areas and techniques to address nutrient loading and run-off, soil requirements for septic systems, and appropriate stormwater collection, detention, and treatment (Leger 1990; Rideout and Adams 1990).

Contemporary efforts to identify and maintain the natural biodiversity of the SWA through surveys, protection actions, management planning, and stewardship have helped to retain rare species and natural communities (Belden 1996; Clampitt *et al.* 1993; Clark 1997; Clark and Potter 1995; Erdle *et al.* 1994; Fleming *et al.* 1998; Fleming and Moorhead 1998; Heffernan 2000; Rawinski and Fleming 1993; Rose *et al.* 1988; Wieboldt *et al.* 1998). Most protected natural areas exist as fragmented pockets in a developed landscape and connectivity declines still more with further human alterations (Godron and Forman 1983). Scattered, unconnected natural areas representing remnants of once-continuous natural habitats have limited potential to provide diverse ecosystem services. One alternative that allows growing human communities and natural systems to coexist is to provide connections between remnant patches of habitat by means of a system of linear open spaces called *conservation corridors*.

Research and development of conservation corridors to retain natural resources and conserve biodiversity is still in its infancy. Nevertheless, a rapidly growing body of literature suggests that corridors, green space, and open land are essential in our fragmented landscape (Burbrink *et al.* 1998; Lindenmayer and Nix 1992; Machtans *et al.* 1996; Noss 1987; Schaefer and Brown 1992). Highly functional presettlement landscapes are known to have been interconnected mosaics of varied habitats, with high connectivity of similar habitats (Noss 1987). Creation and retention of corridors and greenways is an attempt to restore some of the previous landscape connectivity, providing routes for the movement of individuals as well as the gene flow necessary to maintain healthy, viable populations of plants and animals (Yahner and Mahan 1996). Conservation corridors are an important landscape-level approach for restoring and protecting intact ecosystems and providing habitat connections for wide-ranging animals. Appropriately located corridors can be important complements to the strategy of large and multiple reserves (Downes *et al.* 1997; Noss 1987).

In addition to providing wildlife habitat connections and protecting ecosystems, conservation corridors have been used to promote and enhance local parks and recreational interests (City of Raleigh 2000; City of New York 2000; Indy Greenways Plan 1999; Peiser and Schwann 1993; Rails to Trails 2000; Weicher and Zeibst 1973). In Raleigh, North Carolina the Neuse River Corridor Master Plan (2000) offers a working example of greenway corridor design, strategies for establishing buffers, strategies for zoning changes to protect the 100-year flood plain, greenway trail system, and a description of the plan history and implementation. This project uses the Neuse River Corridor to connect a region of parks, nature trails, scenic drives, and educational sites. In New York City, the Department of Parks and Recreation has established a system of greenbelts and formed a non-profit corporation to protect, preserve and manage the Greenbelt Park. The corporation educates the general public and manages an endowment to benefit the greenbelt (New York City 2000).

Protection of water quality, open space preservation, natural resource base retention, and conservation of biodiversity are critical for quality of life and, in the long term, for sustaining the local economies of Chesapeake and Virginia Beach. In working towards these goals, community leaders should consider McAfee (1999) who stated in her paper on "Green Developmentalism" that "…the conservation and sustainable use of biological diversity requires not only global plans and scientific priorities, but also a multiplicity of site-specific, information-intensive technologies relying heavily on inputs of local intelligence and planning to meet local and national needs." Attainment of these goals means working with natural landscapes and processes that, from the human perspective, are

large-scale and long-term. Retaining these values will require a visionary level of planning and implementation.

BACKGROUND INFORMATION

Ecological Significance of the Southern Watershed Area

Occupying the mid-Atlantic seaboard, Virginia is uniquely located both at the northern range limit for many southern species and at the southern range limit for many northern species. The same is true for many naturally occurring community types. Because of this merging of southern and northern affinities, biodiversity of the SWA is remarkable. In addition to hundreds of common plant and animal species, the area supports 19 rare communities as well as 67 plants and 22 animal species that are rare to the state. The SWA is clearly a special area, supported by complex ecological processes. Conservation of these processes, physical landscape components, and the ecosystems they support is critical to the long-term maintenance of the SWA's high level of inherent biodiversity.

Chesapeake and Virginia Beach

The Cities of Chesapeake and Virginia Beach are situated in the southeast corner of Virginia (Figure 1). From a physiographic perspective, they lie on the lower terraces of the Atlantic Coastal Plain Province near the northern end of the Mid-Atlantic Embayed Region stretching from Back Bay in Virginia to the Neuse River embayment in North Carolina (Ward *et al.* 1991). The topography of this area is a nearly level, slightly undulating plain characterized by low elevations, low relief, and abundant wetlands. The land surface consists primarily of near-shore and lagoonal marine deposits punctuated by the Hickory Scarp and the Land of Promise Ridge. These are linear, north-south trending scarps representing two of several successive Pleistocene shorelines (Oaks and Coch 1973; Oaks and Whitehead 1979). Elevations above mean sea level range from less than 1.5 m (5 ft) in floodplains to 7.6 m (25 ft) on the Hickory Scarp. To the east and southeast is Back Bay, an embayed coastal shoreline containing a complex of barrier islands, bays, and sounds which are part of the Albemarle-Pamlico Estuary – one of the largest estuarine systems in the United States (Copeland *et al.* 1983; Dardeau *et al.* 1992).

The northernmost portion of the City of Chesapeake is densely populated urban and suburban land. Central and southern portions of the city are essentially rural and agricultural in character, although residential development has increased significantly in recent years. Extensive, undeveloped areas are still found on the extreme western side of Chesapeake within the Great Dismal Swamp National Wildlife Refuge and in the bottomlands of the Northwest River. The Northwest River is the primary public water supply source for Chesapeake.

The northern and northwestern portions of the City of Virginia Beach are very densely populated urban and suburban lands. The southern portion of the city is agricultural and rural in character. As is the case in many areas of southeast Virginia, residential and industrial development pressures continue to increase. Extensive undeveloped portions of Virginia Beach are found only as protected lands within and adjacent to Back Bay and the North Landing River. Some lands nearby and adjacent to these protected areas are currently undeveloped but are likely to be fragmented and altered in the near future.

Physical and Abiotic Features

Climate. Weather data recorded at Norfolk, Virginia (just north of the Cities of Chesapeake and Virginia Beach) indicate that this region has a climate with hot, humid summers and mild winters. The average annual temperature is 15.3°C (59.5°F), with an average winter temperature of 5.6°C (42°F) and an average summer temperature of 25°C (77°F). The climate is classified as humid-subtropical (Neilson 1976), with a mean annual precipitation of about 45 inches. Heavy rainfall and strong winds associated with tropical storms and hurricanes can occur in summer and fall months. Northeasters, which typically occur during fall and winter, can also generate strong winds and associated heavy precipitation, frequently causing high water levels and local flooding (Bales and Skrobialowski 1994).

Geology and Soils. Portions of Chesapeake and Virginia Beach are underlain by the Poquoson, Lynnhaven, and Sedgefield members of the Tabb Formation (Rader and Evans 1993; Mixon *et al.* 1989). These units are composed of upper Pleistocene sands, silts, clays, and peats deposited on coast-parallel plains east of the Suffolk Scarp. These sediments overlie older Pliocene deposits of the Yorktown Formation (Oaks and Whitehead 1979). Floodplains of the Northwest and North Landing Rivers are mapped as Holocene marsh and intertidal mud deposits (Rader and Evans, 1993). Soils of the City of Chesapeake have been mapped by Henry *et al.* (1959), and soils of the City of Virginia Beach have been mapped by Hatch *et al.* (1985). Soils range from fibric and sapric peat to sandy, silty, and loamy mineral soils with varying degrees of drainage. Somewhat poorly drained to very poorly drained soils dominate the flat, low-lying landscape of this region.

Hydrology. The hydrologic conditions in Chesapeake and Virginia Beach are controlled by varying interactions of groundwater, palustrine-riverine flows, and estuarine processes. Wetland habitats include extensive, saturated or winter-flooded non-riverine flats, a full range of riparian swamps, and upper estuarine marshes and swamps. Even on uplands, the water table is near the surface for much of the year, and elevation differences of only a few centimeters can greatly influence vegetation and drainage. Hydrology of these flat, expansive interfluves has been altered by extensive ditching, which has improved drainage for agriculture and development in many places.

Northwest and North Landing Rivers

The Northwest and North Landing Rivers have similar hydrology. Both rivers emerge from groundwater on somewhat amorphous, peat-mantled landscapes similar to that of the Great Dismal Swamp. In their upper to middle sections, they are each characterized by sluggish, swamp-lined channels and extensive backswamps. In their lower sections, both rivers widen abruptly and become bordered by marshes, reflecting the increasing influence of estuarine processes. South of the Virginia-North Carolina line, each river empties into Currituck Sound, a laterally embayed arm of Albemarle Sound.

The lower Northwest and North Landing Rivers in Virginia represent upstream limits of an estuarine system formed in river valleys drowned by Holocene sea level rise (Copeland *et al.* 1983). While portions of the Albemarle-Pamlico estuary in North Carolina are influenced by diurnal tides, at present the closest open connection to the ocean is approximately 100 km south of the State Line at Oregon Inlet, North Carolina. Consequently, the effect of lunar tides on the Northwest and North Landing Rivers is negligible. However, because the river channels are now oversized for the volume of water they carry, low flow velocities allow irregular wind-driven currents (wind tides) to predominate over riverine flows on a short-term basis (Stanley 1992). Strong winds from the southeast move water northward from Currituck Sound and up the two rivers, flooding fringing marshes and swamps. Conversely, strong north to west winds result in lower water levels. Because wind speeds, direction, and duration are irregular, the frequency and duration of wind tides are highly

variable. Extreme amplitudes of wind tides on the Northwest and North Landing Rivers are not precisely known, but similar wind tides have been estimated to cause as much as 1.2 m (4 ft) of variation in the water surface of the Chowan River in North Carolina, and up to 1.0 m (3.28 ft) of variation in Back Bay, Virginia (Daniel 1977; Norman 1990). Field observations indicate that powerful southerly wind-tidal events during periods of high riverine flow can drive water levels up significantly nearly to the headwaters of these systems and their tributaries.

Salinity

The Northwest and North Landing Rivers also differ from classic tidal estuaries in their salinity regimes. Extensive refractometer measurements made by Fleming and Moorhead (1998) over a two-year period indicate that a freshwater regime (< 0.5 parts per thousand salinity) prevails in these drainages for extended periods, varying into the oligohaline range (0.5 - 5.0 ppt) under certain conditions. The highest salinities (4.0 ppt on the Northwest River and 5.0 ppt on the North Landing River) were measured during a period of very low riverine flow and following a strong southerly wind tide. Such conditions favor the movement of brackish water from Currituck Sound northward into these rivers.

It is likely that both hydrologic conditions and wetland vegetation of the North Landing and Northwest Rivers have been subject to frequent large-scale changes during the Holocene due to rising sea level, peat and sediment accumulation, and instability of the barrier island and Back Bay estuarine landscape. Within the past 350 years, large inlets on the Outer Banks near Back Bay and northern Currituck Sound have opened and closed, for a time allowing brackish/saline water and lunar tides to more directly influence these rivers (Doumlele 1976, Goldsmith 1977, Priest and Dewing 1991). A noteworthy aspect of the present-day river marshes is the prevalence of characteristic brackish marsh plants such as black needle rush (*Juncus roemerianus*) and big cordgrass (*Spartina cynosuroides*), as well as isolated colonies of true halophytes such as salt marsh cordgrass (*Spartina alterniflora*), in an essentially freshwater system. These plants are probably relicts of earlier, more brackish or saline conditions. Moore (1992) has noted that riverine estuaries are frequently characterized by a lack of long-term stability, by transitory biota, and by community composition that fluctuates with controlling environmental factors. Such instability is maintained here by continuing sea level rise, large-scale storm events, and land subsidence in the mid-Atlantic tidewater region.

Human Disturbance History

Although the two rivers are similar in many ways, the North Landing River is a larger system and has a history of major hydrologic disturbances. The Chesapeake and Albemarle (C&A) Canal was constructed in the 1850's to connect the upper part of the North Landing River to the Elizabeth River. The same project involved dredging to straighten, widen, and deepen portions of the river channel from the C&A Canal to Currituck Sound. Several short canals were also dug, cutting off oxbows and creating marsh islands (Clark and Potter 1995). The C&A Canal and North Landing River, along with the Dismal Swamp Canal along US Route 17, are now major components of the Intracoastal Waterway and carry heavy boat and barge traffic. Locks to prevent saline water of the Elizabeth River from reaching the North Landing River were installed on the C&A Canal, but were left open from 1918 to 1932 (Priest and Dewing 1991). In addition, in 1989, a bypass canal was constructed around an older canal which connects West Neck Creek, a major tributary of the North Landing River, to a tributary of the Lynnhaven River, allowing water with salinity up to 24.5 ppt into the North Landing drainage (Bales and Skrobialowski 1993). A recent report on water quality indicates that all 124 river km (77 river mi) of the North Landing River and five of its tributaries fully meet water quality standards for aquatic life support and fish consumption. (VDEQ 2000). DCR's Division of Soil and Water Conservation has given the North Landing River watershed an overall water quality rating of "high" based on nonpoint source contributions from agriculture, urban, and forestry activities (VDEQ 2000).

The Northwest River has not been subject to large-scale disturbances, although a channel was dredged through the headwaters section in the distant past. A number of other minor ditches and canals also drain into upper stretches of the river, but appear to have little hydrologic impact. Much of the lower, estuarine section of the Northwest River is located in North Carolina. A recent report on water quality indicates that all 54 river km (33 river mi) of this stream and two of its tributaries fully meet water quality standards for aquatic life support and fish consumption. DCR's Division of Soil and Water Conservation has given this watershed an overall water quality rating of "high" based on nonpoint source contributions from agriculture, urban, and forestry activities (VDEQ 2000).

Great Dismal Swamp

The Great Dismal Swamp is a vast, forested wetland that lies between the James River (and its tributaries) in southeastern Virginia and the Albemarle Sound (and its tributaries) in northeastern North Carolina. The western boundary of the Swamp is marked by the Suffolk Scarp, a linear, east-facing ridge which represents one of several Pleistocene shorelines in the region. In all other directions, the Dismal Swamp's boundaries are irregular and enclose non-riverine, largely peat-mantled flats not clearly associated with streams or flowing water. The original (pre-settlement) extent of the Swamp cannot now be determined because of a long history of human alterations to the landscape, but was undoubtedly much larger than the current area. Construction of the Dismal Swamp Canal (Intracoastal Waterway) in the early 1800's, altered the hydrology of lands lying to the east of present-day US Route 17 and permitted large areas of swamp to be "improved" (Oaks and Whitehead 1979).

Environmental development of the Great Dismal Swamp began about 12,000 years B.P. (before present) in a cold, late-glacial landscape. Developing wetlands consisted of open freshwater marshes with deep-water aquatic plants, and were confined to the vicinity of stream channels in the eastern part of the area. From about 10,600 to 8,200 years B.P., the climate moderated and marshes and peat deposits expanded to the west and onto the interfluves. From 8,200 to 3,500 years B.P., wetland vegetation shifted from a dominance of grasses and deep-water aquatics to a dominance of emergents and species characteristic of boggy habitats. Westward and lateral expansions of the peat deposits continued. The present-day swamp forest vegetation became established only about 3,500 years B.P. (Whitehead and Oaks 1979).

Early explorers and settlers found the Swamp a dark and forbidding place, but began exploiting its timber resources early in the post-settlement period (Simpson 1990). During the 19th and early 20th centuries, an extensive network of drainage ditches was constructed and the entire area was repeatedly logged and burned. In some cases, historical fires in the Dismal Swamp burned across thousands of acres, destroyed large areas of peat, and burned the roots of countless living trees (Dean 1969; Simpson 1990). As a result of these impacts, original vegetation was destroyed and replaced by secondary forest types that often reflect drier habitat conditions than before.

Despite past disturbances, the Great Dismal Swamp remains one of the largest areas of continuous forest on the Atlantic Coastal Plain and contains an exceptional number of rare communities, plants, and animals. More than 100,000 acres have been acquired by the U.S. Fish and Wildlife Service and are now managed as a National Wildlife Refuge. Several significant outlying areas of swamp habitat, some of them privately owned, also remain.

ECOSYSTEM DESCRIPTIONS

Northwest River

The Northwest River riparian corridor comprises the largest (~15,000 acres) and most important natural area lying entirely within the City of Chesapeake (Figure 1). Headwaters of the Northwest River originate from groundwater, ditches, and drainage on peat-mantled flats just east of U.S. Route 17 and the Great Dismal Swamp. The river flows about 23 river miles to the state line, then for another 10 river miles through North Carolina before emptying into Tull Bay, an embayed arm of Currituck Sound. Major tributaries of the Northwest River in Virginia are Shell Landing Creek, Indian Creek, and Smith Creek. Throughout its short course through Virginia, the Northwest River undergoes a remarkable ecological and hydrological transition. Beginning as a non-riverine, groundwater-controlled wetland, it becomes a sluggish, small coastal plain river winding through expansive swamp forests, then widening into a broad estuarine waterway with wind-tidal fluctuations and marsh-lined channels.

These diverse environmental conditions foster a correspondingly rich assemblage of natural communities, plants, and animals adapted to varied wetland habitats. Adding to this diversity are mesic, forested uplands bordering the swamps and locally occurring as islands within them. Moreover, a significant number of the Northwest River's communities and biotic elements are rare, both in Virginia and globally. Within an immediate area of approximately 12,000 acres, DCR-DNH biologists have identified 17 significant community occurrences, 22 rare plant species, and 12 rare animal species to date (Figure 2). Many of the community types, particularly those associated with non-riverine flats or wind-tidal, oligohaline estuarine environments, are considered globally rare endemics or near-endemics to the mid-Atlantic coastal plain embayed region of southeastern Virginia and eastern North Carolina (Fleming and Moorhead 1998). Among the plant and animal rarities, the rare Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*) occurs throughout the Northwest River drainage, and the area also encompasses one of the last remaining strongholds of the state-listed canebrake rattlesnake (*Crotalus horridus atricaudatus*). Three plants considered globally rare occur here, cypress-knee sedge (*Carex decomposita*), winged seedbox (*Ludwigia alata*), and awned mountain-mint (*Pycnanthemum setosum*).

The City of Chesapeake has supported surveys and conservation work along the Northwest River. Figure 3 shows locations of conservation sites identified to date by DCR-DNH. Available conservation site plans and information on Northwest River sites are found in Appendices B and C, respectively.

Conservation site boundaries mapped in Figure 3 are boundaries which contain all known element occurrences and land determined to be important for long-term maintenance of the elements, or for water quality preservation or enhancement. The Nature Conservancy further describes site conservation boundaries as: "Collectively, the boundaries of the conservation targets and sustaining processes (i.e. ecological boundaries) delineate the functional conservation site – the area necessary to maintain the viability of the conservation targets over time, including the natural patterns and processes that sustain the targets" (The Nature Conservancy 2000a).

The Northwest River riparian corridor provides a relatively large area of connected natural wetland habitats in an otherwise agricultural and residential landscape. Neighboring state-owned and private lands in North Carolina complete an intact and functional wildlife – natural area corridor connecting the Great Dismal Swamp, Northwest River, and North Landing River watersheds (Erdle *et al.* 1994). While the Northwest River is a major recreational resource used for fishing, hunting, and boating it is less impacted by development and receives less recreational use than the nearby North Landing River. This lends a special quality of wildness to the experience of the river and its natural areas.

Approximately 2,250 acres of the middle and lower Northwest River wetlands are owned and managed by DCR as a state natural area preserve. The 763-acre Northwest River Park owned by the City of Chesapeake contains extensive natural habitats. Additional natural areas owned by The Nature Conservancy are also situated along the river east of Route 168 (Battlefield Blvd.), and east of Route 17, north of the river. However, thousands of wetland acres and adjacent forested uplands remain in private ownership. There are many actual and potential threats to this ecosystem, including increased water withdrawal for municipal water supplies, depletion of associated groundwater aquifers, agricultural and urban non-point pollution, fragmentation of large forest blocks, conversion of forest land to non-forest uses, poor forest harvesting practices, and suppression of natural fire regimes in fire-dependent community types (Erdle *et al.* 1994; Fleming *et al.* 1998; Siudyla *et al.* 1981).

North Landing River

The North Landing River watershed covers much of the western and southwestern portions of the City of Virginia Beach and eastern portions of the City of Chesapeake, comprising a total area of approximately 105,600 acres. The North Landing River is ecologically similar to the Northwest River but is a larger stream, with most of its total length in Virginia. It rises from groundwater and drainage in west-central portion of the City of Virginia Beach and flows southward, rapidly widening in its lower reaches before emptying into Currituck Sound just south of the Virginia-North Carolina state line (Figure 1). Like the Northwest River, the North Landing River changes in a remarkably short distance from a groundwater controlled wetland to a sluggish, medium-sized coastal plain river and finally to a broad estuarine waterway with wind-tidal fluctuations and extensive bordering marshes.

The North Landing River and its tributaries support a large concentration of rare species and a diverse array of globally rare and other significant community occurrences, making this an extremely important area for biodiversity conservation in the mid-Atlantic region (Erdle *et al.* 1994). Included are large and outstanding examples of non-riverine swamp forest, pond pine woodland and its high pocosin subtype, peatland Atlantic white cedar forest, and several globally rare types of oligohaline marshes (Fleming and Moorhead 1998). Some noteworthy rare plants and animals in the watershed are the rare Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*), the state-listed canebrake rattlesnake (*Crotalus horridus atricaudatus*), the federally listed Bald Eagle (*Haliaeetus leucocephalus*), and the globally rare plants, Virginia least trillium (*Trillium pusillum* var *virginianum*), cypress-knee sedge (*Carex decomposita*), winged seedbox (*Ludwigia alata*), and Carolina lilaeopsis (*Lilaeopsis carolinensis*)(Figure 2).

The City of Virginia Beach has supported surveys and considerable conservation work along the North Landing River. Locations of conservation sites identified to date by DCR-DNH are shown in Figure 3. Available conservation site plans and information on sites on the North Landing River are found in Appendices B and D, respectively.

Despite its proximity to a major urban area, a history of disturbances, and continued use as part of the Intracoastal Waterway, the North Landing River provides a large, continuous corridor of natural wetland habitats through a landscape otherwise largely agricultural and residential in character. State-owned and private lands in North Carolina partially complete an excellent wildlife/natural area corridor that connects this river with the Northwest River and ultimately the Great Dismal Swamp (Erdle *et al.* 1994; Frost *et al.* 1990). The North Landing River is a major recreational resource used extensively for boating, hunting, and fishing. In 1988, this river and its tributaries were designated a state and local scenic resource according to the Virginia Scenic Rivers Act (Code of Virginia '10.1-

figure 2

figure 3

400 - 418), an act which provides formal recognition but does not establish scenic buffers or restrictions on visual intrusion.

Wetlands along the river have been a major focus of biodiversity protection efforts since 1989. To date, approximately 11,000 acres of wetlands have been acquired by DCR and the Virginia Chapter of The Nature Conservancy and are jointly managed as a natural area preserve (Clark and Potter 1995). Additional public lands are owned by the City of Virginia Beach and the U.S. Army Corps of Engineers. However, most land within the watershed is privately owned. There are many actual and potential threats to this ecosystem, including loss of a natural fire regime, habitat loss and fragmentation, altered surface water quality from agricultural and urban non-point source pollution, groundwater depletion, exotic and invasive species, and recreational over-use (Clark and Potter 1995; Erdle *et al.* 1994; Siudyla *et al.* 1981; Stevens and Patterson 1998).

Back Bay

The Back Bay watershed is nestled in the southeastern most corner of the state and comprises approximately 66,750 acres, including 25,100 acres of open water. Back Bay, the northern portion of the Currituck Sound embayment, is a large body of brackish water lined by marshes, shrubby wetlands, and swamps. The entire embayed area is separated from the Atlantic Ocean by a relatively narrow sand spit, which has historically been breached and broken repeatedly, creating temporary inlets. Since the closing of Currituck Inlet during a storm in 1830, Back Bay has changed from a tidally influenced saltwater estuary to a wind tide dominated fresh/brackish estuary.

Included in the Back Bay watershed are several smaller waterbodies such as Redwing Lake, Brinson's Inlet Lake (Lake Tecumseh), and Black Gut, as well as extensive agricultural areas on uplands. Major tributaries to Back Bay include Muddy Creek, Beggar's Bridge Creek, Nawney Creek, Devil Creek, Black Gut, Ashville Creek, Hell Point Creek, Scopus Marsh, and Lake Tecumseh (Figure 1). Some marshes are dominated by common reed (*Phragmites australis*), an invasive grass that grows to 10-ft and taller and can rapidly colonize and completely occupy adjoining areas. Other marshes are in their natural state and support a more diverse mosaic of vegetation types. Prevalent species in these natural marshes include big cordgrass (*Spartina cynosuroides*), narrow-leaved cattail (*Typha angustifolia*), Olney's bulrush (*Scirpus olneyi*), and black needle rush (*Juncus roemerianus*).

Back Bay, the adjacent uplands, and tributaries support a large concentration of rare species and a diverse array of globally rare and other significant community occurrences, making this an extremely important area for biodiversity conservation in the mid-Atlantic region (Clampitt *et al.* 1993). Eight rare ecological communities have been documented from the Back Bay watershed. Included are a significant barrier beach system, maritime dune grasslands, maritime shrub swamps, and one of the region's finest maritime evergreen forests, as well as several globally rare types of oligohaline marshes (Clampitt *et al.* 1993; Fleming and Moorhead 1998). Among the 40 rare plant occurrences are fibrous bladderwort (*Utricularia striata*), sticky ground-cherry (*Physalis walteri*), bay-gail holly (*Ilex coriacea*), cottony golden-aster (*Chrysopsis gossypina*), and pale grass–pink (*Calopogon pallidus*). The Back Bay watershed supports 10 rare animals, including the federally listed Bald Eagle (*Haliaeetus leucocephalus*), state-listed canebrake rattlesnake (*Crotalus horridus atricaudatus*), Least Bittern (*Ixobrychus exilis*), loggerhead turtle (*Caretta caretta*), stripe-winged baskettail (*Epitheca costalis*), and eastern glass lizard (*Ophisaurus ventralis*)(Figure 2).

Wetlands and uplands of Back Bay have been the focus of conservation and resource management activities by both the state and federal government. Within this watershed are two National Wildlife Refuges (NWR), Back Bay NWR and Mackay Island NWR, False Cape State Park, False Cape Natural Area Preserve, and two state Wildlife Management Areas (WMA), Trojan WMA and

Pocahontas WMA. Back Bay is an important wintering ground for a number of game waterfowl, and consequently the watershed has also been designated as the Back Bay Focal Area, a component of the North American Waterfowl Management Plan. Large, unfragmented forests in the Back Bay watershed also serve as critical stopovers for neotropical migratory songbirds and migrating shorebirds. In addition to fishing and hunting, other recreational activities in Back Bay watershed include canoeing, water skiing, boating, biking and camping (Erdle *et al.* 1994; Mabey *et al.* 1993).

The City of Virginia Beach and several federal agencies have supported extensive surveys and conservation work in the Back Bay watershed (see Figure 3 for locations of conservation sites identified by DCR-DNH). Available conservation site descriptions and site information for sites in the Back Bay watershed are found in Appendix E.

Long-term health of Back Bay and its associated waterways is threatened by non-point source water pollution, further fragmentation of existing forested lands, groundwater pollution, invasive species, and recreational over-use. In recent years, there has been a precipitous decline in the amount and health of submerged aquatic vegetation (SAV) in Back Bay, a likely result of decreased water quality / increased turbidity (Morton and Kane 1994; Siudyla *et al.* 1981).

NATURAL RESOURCES

The SWA supports a multitude of natural resources, including extensive wetlands, productive forest and agricultural lands, mineral resources, extensive waterways for boating and fishing, hunting for a variety of game species, recreational beaches, and numerous other water-related recreational opportunities. Along with its well-known tourist beaches, the area features a coastal state park, national wildlife refuges, and other public and private protected lands that represent critically important habitats for migratory birds, including both waterfowl and land-bird species. These in turn support outdoor recreation activity that includes bird- and wildlife-watching, plus a long tradition of waterfowl hunting in and around Back Bay and its extensive marshlands.

In addition to the many natural resources with which most residents, visitors, and tourists are familiar, the SWA also supports a remarkable array of *natural heritage resources*. These are the habitats of rare, threatened or endangered plant and animal species, rare or state significant communities, and other natural features. DCR-DNH has documented the presence of 19 rare natural communities, 67 rare plants, and 22 rare animals within the SWA (see Figure 2 for general locations of these natural heritage resource occurrences).

Natural Communities

The SWA lies near the northern terminus of the Southeastern Evergreen Forest Region, which stretches from southeastern Virginia to eastern Texas on the Atlantic and Gulf Coastal Plains (Braun 1950). This region is characterized by a prevalence of pine and pine-hardwood communities along with large areas of swamp forest and bottomland hardwoods along rivers and drainageways, plus local areas of mesic hardwood forest on uplands. A more recent classification (Keys *et al.* 1995) includes the SWA within the Outer Coastal Plain Mixed Forest Province, Atlantic Coastal Flatwoods Section, Tidal Area Subsection. Potential natural vegetation of the Tidal Area Subsection is characterized by pond pine – Atlantic white cedar – red maple forest, loblolly bay – pond pine forest, and black needlerush marsh communities. Scientific names for natural communities used in this plan are based on the classification work of Fleming and Moorhead (1998). While community names follow a standard list maintained by DCR-DNH (Fleming *et al.* 2001), many are adapted from Schafale and Weakley (1990).

There are many reasons to protect and conserve natural communities of plants and animals, both terrestrial and aquatic. In particular, rare communities – those with few remaining examples or occurrences – are especially in need of protection. Communities represent functioning units of the landscape that:

- support myriad life forms—many too cryptic or poorly known to be catalogued and prioritized individually;
- provide required habitat and symbiotic relationships for both rare and common species;
- comprise the living component of local ecosystems;
- possess unique scientific, educational, and aesthetic values.

Community Types

Upland forests. This type includes both infertile, dry oak-hickory forests of xeric sandy uplands and somewhat infertile to moderately fertile mesic mixed hardwood forests of well-drained uplands and slightly elevated "islands" within swamps. Dry oak-hickory forests are locally common in the Virginia coastal plain but rare in the generally flat, poorly drained landscape of the City of Chesapeake. Characteristic trees include white oak (*Quercus alba*), southern red oak (*Quercus falcata*), post oak (*Quercus stellata*), water oak (*Quercus nigra*), mockernut hickory (*Carya alba*), sand hickory (*Carya pallida*), and loblolly pine (*Pinus taeda*). Understory and shrub species include flowering dogwood (*Cornus florida*), sourwood (*Oxydendrum arboreum*), horse-sugar (*Symplocos tinctoria*), and ericaceous (heath-family) shrubs such as lowbush blueberry (*Vaccinium pallidum*), black huckleberry (*Gaylussacia baccata*), and mountain-laurel (*Kalmia latifolia*l). Mesic mixed hardwood forests are widely distributed in fragmented patches in the southeastern corner of the Virginia and southward on the outer coastal plain. They have been much reduced by agricultural conversion, logging, and development. Significant occurrences represent the most mature and floristically distinctive stands. Characteristic species include American beech (*Fagus grandifolia*), white oak, tuliptree (*Liriodendron tulipifera*), hickories (*Carya* spp.), American holly (*Ilex opaca*), eastern hophornbeam (*Ostrya virginiana*), silky camellia (*Stewartia malacodendron*), and Christmas fern (*Polystichum acrostichoides*). Upland forests are important habitats for migratory songbirds, many common mammals, and the state endangered canebrake rattlesnake (*Crotalus horridus atricaudatus*).

Peatland Evergreen Forests. This class includes Atlantic white cedar forests and pond pine woodlands, both characterized by coniferous canopy trees and broad-leaved evergreen shrub layers. Characteristic trees of this class include Atlantic white cedar (*Chamaecyparis thyoides*) and pond pine (*Pinus serotina*), as well as broad-leaved evergreen bay species such as sweetbay (*Magnolia virginiana*) and red bay (*Persea palustris*). Typical shrubs include shining fetterbush (*Lyonia lucida*), inkberry (*Ilex glabra*), laurel-leaf greenbrier (*Smilax laurifolia*), and highbush blueberry (*Vaccinium corymbosum*). Sparsely canopied, densely shrubby stands of pond pine woodland are commonly known as high pocosins (Fleming and Moorhead 1998). Confined to saturated peat substrates and fire-influenced habitats, community types of this group are rare and declining in Virginia, due to widespread fire reduction, logging, and habitat destruction. Occurrences in the SWA tend to be small and confined to peat flats along the Northwest and North Landing Rivers (with additional limited occurrences in the Great Dismal Swamp).

Flooded Swamp Forests. This class encompasses swamp forests of coastal plain floodplains and poorly drained interstream flats subject to seasonal or semi-permanent inundation. Characteristic plants of the class include baldcypress (*Taxodium distichum*), swamp tupelo (*Nyssa biflora*), water tupelo (*Nyssa aquatica*), red maple (*Acer rubrum*), ashes (*Fraxinus* spp.), Virginia willow (*Itea virginica*), and lizard's tail (*Saururus cernuus*). Community types include seasonally to

semipermanently flooded tupelo-baldcypress swamps of eutrophic river basin flats; sloughs and backswamps; seasonally flooded coastal plain bottomland hardwoods of mineral soil swamps along smaller tributary streams; estuarine fringe swamp forests of wind tidally flooded peatlands bordering the North Landing and Northwest Rivers; and seasonally flooded non-riverine swamp forests of interfluve peat or clay flats. Evidently confined to the mid-Atlantic coastal embayed region, the last two types are globally rare, although locally common in this region (Fleming and Moorhead 1998). In the City of Chesapeake, flooded swamps provide large expanses of unbroken natural habitat in a landscape otherwise dominated by agricultural and residential uses. Consequently, they are very important to a large array of nesting birds, mammals, amphibians, reptiles, and invertebrates.

Non-Riverine Saturated Forests. This class includes forests of saturated interstream flats with perched water tables and mineral soils, or thin organic soils. Most common is non-riverine pine-hardwood forest, a successional unit dominated by loblolly pine, red maple, sweetgum (*Liquidambar styraciflua*), often with a dense giant cane (*Arundinaria gigantea* ssp. *tecta*) understory. Non-riverine wet hardwood forest, characterized by hydrophytic oaks such as swamp chestnut oak (*Quercus michauxii*) and laurel oak (*Q. laurifolia*) is evidently confined to the embayed region of the mid-Atlantic coastal plain. This community type is highly threatened by drainage, logging, and outright destruction by development, and is now generally limited to small patches.

Oligohaline Tidal Marshes and Woody Ecotones. Marshes and related shrubland and woodland communities occupying low-salinity estuarine environments comprise this class. These communities occur in patch mosaics along the lower Northwest River and along the most downstream portions of the North Landing River located in the City of Chesapeake. Woody vegetation includes tidal baldcypress woodland/savanna and tidal shrub swamp. Marsh vegetation is typically mixed and includes community types characterized by big cordgrass (*Spartina cynosuroides*), black needlerush (*Juncus roemerianus*), and spikerushes (*Eleocharis* spp.). Although both big cordgrass and black needle rush communities are typical of brackish marshes, those of the nearly fresh, wind tidal marshes of the Albemarle-Pamlico estuary are considered to be somewhat unique in their floristic composition and preponderance of freshwater associates. Virtually all community types in this class are considered more or less globally rare due to their geographic restrictions and narrow habitat requirements (Fleming and Moorhead 1998). The marshes provide important habitats for aquatic mammals, breeding waterfowl, and amphibians.

Oligohaline Floating / Aquatic Vegetation. A single community type in this class, best developed in shallow, protected guts and pools in the wind tidally flooded marshes of the Northwest River, is recognized in the SWA. Characteristic species are common hornwort (*Ceratophyllum demersum*), greater bladderwort (*Utricularia macrorhiza*), American water-lily (*Nymphaea odorata*), and other floating or submergent macrophytes. These aquatic habitats are important breeding and foraging sites for damselflies and dragonflies, specialized insects, crustaceans, amphibians, reptiles, and some fish.

Brackish and Saline Tidal Marshes. Lunar tidal brackish and salt marshes occur in the northern portion of the City of Chesapeake along branches of the Elizabeth River. Marshes characterized by saltmarsh cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), saltgrass (*Distichlis spicata*), and black needlerush (*Juncus roemerianus*) were observed in a number of localities. These marshes are extremely important as habitats for breeding and migratory waterfowl.

Rare Communities. A total of 19 rare community types, classified as significant by DCR-DNH, have been documented from the SWA (Figure 2). Table 1 lists these communities and their global and state status ranks. Comprehensive descriptions of the wetland community types are found in Fleming and Moorhead (1998) and Fleming *et al.*, 2001. Descriptions of significant occurrences are provided in the appended conservation site reports. Some community types are yet to be officially

ranked while ongoing efforts by Natural Heritage programs continue that will determine global community ranges and number of occurrences.

Table 1. Rare Natural Communities of the Southern Watershed Area

Common Name	Global and State Rarity Ranks
bald cypress-tupelo swamp	G5?* S4
coastal plain bottomland hardwood forest	G3G4 S2?
estuarine fringe swamp forest	G2? S1S2
high pocosin	G2? S1S2
maritime evergreen forest	G2? S1
maritime scrub	G? S2
maritime shrub swamp	G? S2
maritime wet grassland	G? S2
mesic mixed hardwood forest	G? S3?
non-riverine swamp forest	G2G3 S1S2
non-riverine wet hardwood forest	G2 S2
pond pine forest / woodland	G2? S1S2
peatland Atlantic white cedar forest	G2 S1
tidal bald cypress woodland / savanna	G1Q S1
tidal oligohaline marsh – big cordgrass type	G2G3 S2S3
tidal oligohaline marsh – black needlerush type	G2G3 S2S3
tidal oligohaline marsh - spikerush type	G1G2 S1
tidal pool gut	G3? S1
tidal shrub swamp	G2G3 S2

*Community ranks with a question mark are awaiting official ranking.

Plants and Animals

Rare species are defined in terms of the number of known occurrences range-wide (global or G-rank) and also relative to the number of occurrences within the Commonwealth (state or S-rank). They include species with global ranks of G1, G2, G3 and G4, and state ranks of S1, S2, S3, SH, SX, and SU. Data on species with state ranks of S1, S2, SH, and SX (see Appendix A for symbol explanation) are summarized on periodically-updated master lists of Virginia's rare plants (Belden 1999) and rare animals (Roble 1999). Species with state ranks of S3 and SU are maintained on a separate "watch list." Only general information about watch list species is recorded in the field and maintained in DCR-DNH manual information files.

Plants. The SWA supports hundreds of plant species, both common and rare. Some of the species are well known, and have long documented and anecdotal histories such as giant cane (*Arundinaria gigantea* ssp. *tecta*). While native vegetation is a critical natural resource, attention is focused here on the uncommon or rare plant species. A listing of the rare plants of the SWA is provided in Table 2.

Table 2. Rare Plants of the Southern Watershed Area

Scientific Name	Common Name	Global and State Rarity Ranks
Aster puniceus var *elliottii*	Elliott's aster	G5T3T4 S1

Calephelis virginiensis	little metalmark	G4 S2
Calopogon pallidus	pale grass-pink	G4G5 SH
Carex decomposita	epiphytic sedge	G3 S2
Carex lupuliformis	false hop sedge	G3? S1
Carex reniformis	reniform sedge	G4? SH
Chamaesyce bombensis	southern beach grass	G4G5 S2
Chrysopsis gossypina	cottony golden-aster	G5 S1
Cladium jamaicense	sawgrass	G4 S1
Cleistes divaricata	spreading pogonia	G4 S1
Coreopsis falcata	pool coreopsis	G4G5 S1
Crataegus aestivalis	may hawthorn	G5 S1
Cuscuta cephalanthi	button-bush dodder	G5 S1?
Cuscuta indecora	pretty dodder	G5 S2?
Cuscuta polygonorum	smartweed dodder	G5 S2?
Dichanthelium consanguineum	blood witchgrass	G5 S1?
Eleocharis halophila	salt-marsh spikerush	G4 S1
Eleocharis radicans	rooted spikerush	G5 SH
Eleocharis vivipara	viviparous spikerush	G5 S1
Enallagma pallidum	pale bluet	G4 S1
Erigeron vernus	white-top fleabane	G5 S2
Eriocaulon decangulare	ten-angle pipewort	G5 S2
Heliotropium curassavicum	seaside heliotrope	G5 S1
Hottonia inflata	featherfoil	G4 S2S3
Hydrocotyle bonariensis	coastal-plain penny-wort	G5 S1?
Ilex coriacea	bay-gail holly	G5 S2
Iva imbricata	sea-coast marsh-elder	G5? S1S2
Juncus elliottii	bog rush	G4G5 S1S2
Juncus megacephalus	big-head rush	G4G5 S2
Kalmia carolina	Carolina sheep-laurel	G4 S2
Lilaeopsis carolinensis	Carolina lilaeopsis	G3? S1
Lipocarpha maculata	a lipocarpha	G5 S1
Lobelia elongata	elongated lobelia	G4G5 S1
Ludwigia alata	winged seedbox	G4 S1
Ludwigia brevipes	long beach seedbox	G4G5 S2
Ludwigia ravenii	raven's seedbox	G2? S1
Ludwigia repens	creeping seedbox	G5 S1
Ophioglossum petiolatum	longstem adder's-tongue	G5 SH
Panicum hemitomon	maidencane	G5? S2
Paspalum dissectum	water paspalum	G4? S2
Paspalum distichum	joint paspalum	G5 S1
Phlox pilosa ssp pilosa	downy phlox	G5T5 S2
Phyla nodiflora	common frog-fruit	G5 S1
Physalis walteri	sticky ground-cherry	G4 S2
Physostegia leptophylla	slender-leaved dragon-head	G4? S2S3
Pycnanthemum setosum	awned mountain-mint	G3? S1
Quercus hemisphaerica	Darlington's oak	G5 S1
Quercus incana	blue jack oak	G5 S2
Ranunculus hederaceus	long-stalked crowfoot	G5 SH
Rhynchospora cephalanatha var.	many-headed beakrush	G5T? S2

pleiocephala		
Rhynchospora colorata	white-topped sedge	G5 S1
Rhynchospora debilis	savannah beakrush	G4? S1
Rhynchospora fascicularis var *fascicularis*	fasciculate beakrush	G5T? S1?
Rhynchospora macrostachya var. *macrostachya*	tall horned beakrush	G4T? S2
Solidago latissimifolia	Elliott goldenrod	G5 S2
Solidago tortifolia	a goldenrod	G4G5 S1
Sphagnum macrophyllum var macrophyllum	large-leaf peatmoss	G3T3 S2
Sphagnum trinitense	Trinidad peatmoss	G4 S2S3
Stachys aspera	rough hedge-nettle	G4? S2
Tillandsia usneoides	spanish moss	G5 S2
Trillium pusillum var virginianum	Virginia least trillium	G3T2 S2
Utricularia purpurea	purple bladderwort	G5 S2
Utricularia striata	fibrous bladderwort	G4G5 S1
Vaccinium macrocarpon	large cranberry	G4 S2
Verbena scabra	sandpaper vervain	G5 S2
Xyris fimbriata	fringed yellow-eyed-grass	G5 S1
Xyris iridifolia	irisleaf yellow-eyed grass	G4G5T4T5 S1

*Rare plant ranks with a question mark are awaiting official ranking.

Animals. The SWA supports hundreds of animal species, both common and rare. Some of the species are well known, and have long documented, as well as anecdotal histories such as the black bear (*Ursus americanus*), the white-tailed deer (*Odocoileus virginianus*), and the Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*). While all native animals are critical natural resources, attention here is focused on the uncommon or rare animal species. A listing of the rare animals of the SWA is provided in Table 3.

Table 3. Rare Animals of the Southern Watershed Area

Scientific Name	Common Name	Global and State Rarity Ranks
Siren lacertina	greater siren	G5 S2
Crotalus horridus atricaudatus	canebrake rattlesnake	G4TUQ S1
Ophisaurus ventralis	Eastern glass lizard	G5 S1
Ardea alba	Great Egret	G5 S2BS4
Haliaeetus leucocephalus	Bald Eagle	G4 S2
Ixobrychus exilis	Least Bittern	G5 S2
Limnothlypis swainsonii	Swainson's Warbler	G4 S2
Rallus elegans	King Rail	G4G5 S2
Rallus limicola	Virginia Rail	G5 S2
Corynorhinus rafinesquii	eastern big-eared bat	G3G4 S1
Myotis austroriparius	southeastern myotis	G3 S1
Sorex longirostris fisheri	Dismal Swamp southeastern shrew	G5T2T3 S2
Utterbackia imbecillis	paper pondshell	G5 S2S3
Pseudopolydesmus paludicolous	a millipede	G1 S1
Altides halesus	great purple hairstreak	G5 S2S3
Epitheca costalis	stripe-winged baskettail	G4 S2

Euphyes dukesi	scarce swamp skipper	G3 S2
Euphyes pilatka	saw-grass skipper	G3G4 SH
Chlorachroa dismalia	Dismal Swamp green stinkbug	G2 S1
Ploiaria hirticornis	an assassin bug	G3? S1
Cicindela trifasciata	a tiger beetle	G5 S1

*Rare animal ranks with a question mark are awaiting official ranking.

DEVELOPMENT OF CONSERVATION CORRIDORS

Conservation corridors are linear green-belts or open-space that ideally connect larger, undeveloped areas of natural vegetation. Designating conservation corridors in advance of a fast-developing urban landscape is a proactive approach for retaining natural landscape connectivity, natural resources, and other open-space benefits. Corridors situated in already developed areas have great potential for restoring open-space and landscape level ecosystem functions in localities that have undergone rapid urban growth. Connecting remnant patches (fragments) of natural habitat optimizes the use of land as open-space and increases the functions of natural areas that remain within an overall landscape context of intensive human use. A system of conservation corridors will sustain natural communities and populations of native plants and animals while also providing a multitude of values to society, including:

- protection of riparian systems;
- improved surface and ground water quality;
- reduced air and noise pollution
- recreational opportunities such as wildlife-watching, canoeing, kayaking, hunting and fishing where appropriate, walking, hiking, and bicycling;
- natural history, natural resource conservation, and biological educational opportunities;
- enhanced property values;
- improved quality of life.

Need for a New Conservation Strategy

Many localities have seen the need to plan patterns of urban development in ways that retain open space and have developed programs that designate green belts, greenways, and conservation corridors (City of Raleigh, NC 2000; City of New York 2000; Indy Greenways Plan 1999; Roanoke Valley Greenways 2000). While requiring dedication of substantial land area for their creation, corridors have immeasurable tangible and intangible value. Retained green space enhances real estate values of neighboring and nearby property (Adams and Mundy 1991; Fausold and Lilieholm 1999; Vicary 1994) and riparian corridors protect drinking water supplies. Along with improved water quality and reduction of air and noise pollution, benefits to the community from retained open space in conservation corridors include enhanced recreational opportunities such as fishing, hunting, canoeing, boating, walking, running, bicycling, and wildlife-watching. Opportunities for outdoor education, natural history interpretation, and nature-based tourism businesses are improved as well.

The northern portions of Virginia Beach and Chesapeake have been intensively developed and urban sprawl is now rapidly advancing southward. As of January 2001, the middle and southern portions of the SWA remain somewhat rural with a landscape comprised of agricultural and forest lands (Figure 4). However, residential and commercial land uses are increasing rapidly. Development of the SWA during the 1990's has heightened concerns for preserving water quality, retaining land uses associated with farm and forest land, and maintaining rural character of the area. To address these concerns, a

figure 4

new way of thinking about conservation is required that will allow continued acceptable development while retaining some undeveloped lands that provide the values and benefits of open space.

The North Landing River, Northwest River, and Back Bay watersheds are bordered by relatively intact riparian corridors consisting of more or less continuous linear areas of mostly wetland forest vegetation. These corridors persist in part because hydric soils have prohibited conversion to other land uses, but also because of conservation actions by public and private organizations to acquire and protect these areas. Figure 5 maps the public lands and private protected lands in and adjacent to the SWA. Through the efforts of local, state, and federal agencies as well as private organizations, the SWA still supports examples of functioning ecosystems which provide relatively clean water and a multitude of other benefits. However, as the area becomes more urban, water quality is threatened by increased nutrient, sediment, and chemical inputs from commercial and residential developed areas. Habitat for a high diversity of wildlife species, outdoor recreational opportunities, and scenic values of rural landscapes will decline and finally be eliminated unless additional measures to retain open space are taken.

Additional corridor lands could include restored areas of both currently developed areas plus marginal crop lands. Increasing buffer zone width would offer greater protection to tributary creeks, marshes, and primary water courses and ensure a high quality supply of municipal water in the SWA. Effects of habitat fragmentation on wildlife movements would also be reduced by connections provided by large unbroken linear forest. Public demands for recreational uses such as walking, running, hiking, and interpretive nature trails and water trails for canoes and kayaks could be met while still providing sufficiently large patches of habitat for natural areas and sustainable stewardship forests.

A successful conservation strategy for the SWA must determine how to maintain water quality, functioning ecosystems, and rural land uses. Future work should build on accomplishments to date, and lead to protection of attributes and qualities important to the health of both humans and other native life forms of the area. The challenge is to accomplish this goal in a rapidly developing, human-dominated landscape setting.

Conservation Corridor Options

When designing conservation corridors, it is essential to consider: 1) original goals for the corridor initiative; 2) larger natural areas to be connected by the corridors and resources that they support; 3) various uses that take place in the corridors presently and potentially; 4) wildlife species that use or may use the corridors in the future, plus their ecology, habitat requirements, and movement abilities; 5) human/wildlife interactions; and 6) future considerations such as development pressure, economic change, local long-term planning, and for coastal areas - sea-level rise (Pugh 1994).

To adequately address wildlife habitat requirements, a conservation corridor system should encompass: 1) multiple pathways linking retained habitat; 2) reservation of larger areas of suitable habitat at periodic intervals along corridors; 3) linked corridors representing a sample of existing topographic and habitat types; 4) a hierarchy of corridors comprised of broad regional corridors established to restore links between isolated forests, major wildlife corridors within production forests to link important reserved areas and a network of smaller wildlife corridors forming common linkages in the system of retained habitat (Miller *et al.* 1998; Pugh 1994;).

Five conservation corridor options are presented below. These options are named using the term *density* (commonly used to describe numbers of items within a unit of area). In this context, *density* refers to the amount of conservation corridor area within the SWA. Options are presented in order of

increasing *density*, from lowest to highest. Also included are descriptions, possibilities, and general conservation and protection considerations.

Low corridor density. This lowest level conservation option is comprised of the current acreage (30,307.2 acres, Appendix F) of public and private protected lands in the SWA (Figure 6). Many of these areas are located within the riparian zones of the Northwest River, North Landing River, or Back Bay. Following riparian borders, these lands are mostly linear in arrangement. However, they do not currently form a cohesive, contiguous, and connected system of protected lands. Large areas between parcels are not presently protected from development or land-use alterations. As present patterns of urban growth continue, habitat fragmentation will further alter the landscape, eventually eliminating corridors for wildlife movement and genetic exchange, and decreasing open space recreational opportunities. Rural land uses on low uplands and drained agricultural fields between protected wetlands will be replaced by developments. As this pattern continues and culminates, current levels of water quality are unlikely to be maintained. While some further acquisition of land for natural areas may occur in the SWA, it is presently improbable that a cohesive corridor development effort will occur.

Moderate-low corridor density. Figure 7 displays a second level of conservation corridor density. This option includes both currently-protected lands plus those linear areas (within watersheds) that connect them – up to a width of one-half mile (50248.7 acres, Appendix F). This corridor plan would require establishing minimal connections through various land protection tools such as conservation easements and purchases from willing sellers. Habitat restoration and mitigation lands would be appropriate and recommended for land areas acquired within the connecting corridor zones. Adoption of this moderately low conservation corridor density would provide somewhat increased potential for long-term water quality protection and riparian habitat protection. It would also link currently-protected public and private conservation lands, and provide a permanent habitat connection between the Great Dismal Swamp and Currituck Sound ecosystems via the Northwest River. The resulting minimal, although improved, corridor system would provide some increased benefits. However, considerable habitat fragmentation and loss would continue to occur as large areas of rural land are eliminated. Overall, only small additional resources would be protected from land-use alterations with this density of conservation corridors.

Medium corridor density. Under a third scenario that would result in a medium level of corridor density, the simple corridor system defined in the previous example is augmented by additional unprotected Natural Heritage Conservation Sites from the SWA (total of 94,853.4 acres, Appendix F). These Conservation Sites consist of those areas identified to date by DCR-DNH scientists (see Appendices C, D, and E) that support occurrences of Natural Heritage Resources. While some are disjunct fragments, most sites form distinct and continuous corridors in the Northwest River, North Landing River, and Back Bay watersheds (Figure 8). Some Natural Heritage Conservation Sites are publicly owned; however, most are in private ownership with many in agricultural use. Such areas, once acquired from willing sellers or included under purchased easements, would be promising locations for mitigation banks and habitat restoration projects. Appropriate, sustainable silvicultural land uses could be compatible with other resource protection and habitat management objectives. Attaining this level of conservation corridor density in the SWA would greatly facilitate water quality enhancement objectives, wildlife migrations, plant dispersal, and recreational opportunities. Along with a successfully adopted Agricultural Conservation Plan, preservation of a rural landscape might be attainable with this option.

Moderate-high corridor density. A fourth level of resource conservation proposed for the SWA would involve moderately-high corridor density and include (1) existing public and private conservation lands, (2) known Natural Heritage Conservation Sites, and (3) half-mile wide corridors,

figure 5

figure 6

figure 7

figure 8

that establish connections between the three watersheds, forming a network of connected conservation lands (Figure 9) (99,339.2 acres, Appendix F). Adding connecting corridors that link protected lands with sites that still support rare species and communities will effectively achieve multiple conservation goals. Such connections enable wildlife movements and provide functional, manageable habitats; create diverse and abundant recreational activities; represent additional protections to groundwater resources and surface water quality. Designating this level of open-space protection will assist retention of the rural character of the SWA. Lands included within defined corridors would be primary considerations for mitigation banks, restoration, and mitigation efforts. Over a long time period – perhaps 50 years or more –land uses within designated corridors would be shifted to less intensive uses such as forest and wildlife management, recreation, and where appropriate, natural areas management. Habitat restoration projects would be needed to convert hardened surfaces and remove infrastructure. As a large proportion of lands delineated in this option are in private ownership, clear messages will have to be sent about the means by which lands or property rights might be acquired. Any resource protection measures should involve willing sellers and fair market compensation for property or ownership rights in order to move forward with this or other initiatives.

High corridor density. This option proposes a maximal corridor density for the SWA and would yield by far the highest returns (113,581.1 acres, Appendix F) in resource protection and open-space benefits and values (Figure 10). It would also cost the most and be the most difficult proposal to implement of all those suggested. High conservation corridor density would link the Great Dismal Swamp with the North Landing River, Northwest River, and Back Bay ecosystems and represent an exceptional commitment to retaining the natural resource base of the SWA. This level includes public and private conservation lands, Natural Heritage Conservation Sites, lands connecting them, plus additional corridors to further restore landscape connectivity in order to achieve a variety of purposes. Much of this land area would be designated as future open-space and include currently developed land uses that would be restored over time. The result would be outstanding opportunities for outdoor recreation, protection of the rural landscape, ensured water quality, extensive lands continuously available for forestry and some agricultural uses. Figure 11 maps this conservation corridor density with selected land uses in the SWA. As stated above, private property rights considerations should be paramount in any discussions and implementation strategies, since most lands designated within corridors are privately owned. Fee simple purchase, conservation easements, purchase of development rights, or agricultural reserve programs are known methods by which fair compensation can be made. Extensive areas are already in some state of development, while others are undergoing land-use alterations. Many (if not most) areas within corridors would require hydrologic and vegetative restoration representing many opportunities for mitigation.

The high levels of conservation corridor density proposed here are perhaps best described as planning tools and could not be implemented over short time periods – and quite possibly, not at all. It is hoped that proposing these various levels of conservation corridor will be viewed not as ludicrous but, rather, as visionary. Figure 12 maps a comparison of the five levels of conservation corridor densities presented here, and Appendix F summarizes this information in tabular form. Localities that choose to consider such means for conserving open-space and retaining the quality of life that hinges on retaining natural resources will be lauded as forward thinking. Those that implement such programs will undoubtedly be recognized as progressive, in a new sense. This, of course, is ironic since the term “progress” once inferred unrestrained development.

STEWARDSHIP OF CORRIDOR HABITATS

Public Use

One of the strongest justifications for retaining open space in rapidly expanding population centers is to maintain places for the residents of a community to recreate and maintain connections with the natural world. Greenways, blueways, and urban trails have become part of major corridor planning efforts and catalysts for far-reaching programs of open space preservation. Competition becomes high for public use of open space as available undeveloped land becomes scarce and as real estate values soar. Thus, demand will be high for public use of land within retained conservation corridor lands. Compatible use determinations will be required to ensure that the values provide by "urban wildlands" are not compromised by public users who, sometimes simply by their presence, can "love a place to death." Appropriate uses for core natural areas might be limited to passive recreation such as wildlife watching, photography, hiking, canoeing, and natural history education. Connecting corridor lands however, might easily sustain more active recreational use, as well as forest management, agriculture, and low density and low impact development. High water quality that results from strong conservation measures will result in increased recreational fishing opportunities. In some areas, hunting may be both compatible with the conservation mission of these lands and also necessary to control expanding populations of whitetail deer.

Hydrologic Restoration

Following designation and protection actions, areas of former agricultural lands within conservation corridors may be desirable for hydrological restoration to reinstate former wetland processes. Restored hydrology will be a cornerstone upon which a return to natural community types, including forested wetland habitats, will be based. Methods to restore former soil moisture regimes may include: 1) blocking existing drainage ditches and canals; 2) removing existing field tile systems; and 3) construction of water control structures.

Water Quality Monitoring

For many reasons, the issue of water quality is of special concern and is a great priority in the SWA. Thus, it is imperative to closely monitor the status and condition of water supplies either under scenarios of unplanned sprawl, or during implementation of new conservation initiatives. If conservation corridors are protected, then riparian buffer areas will expand, distances between developed and paved areas will increase, and the positive impacts on water quality should be demonstrable. An intensive program to measure and report increases in SWA surface and ground water quality may give the most objective and quantifiable expression of success of landscape-level conservation actions.

Prescribed Fire

To prevent unnatural accumulations of forest fuels and to maintain fire-dependant natural communities, land managers responsible for the maintenance of community structure and composition in natural areas within conservation corridors are likely to require the use of prescribed burning. Fire, with all of its well-known negative and harmful connotations, is also a beneficial tool that can yield many positive effects when used in appropriate ways and under the right circumstances. For example, marsh communities along riparian zones of SWA rivers require periodic burning to retard invasion by trees and shrubs. Evergreen shrub bogs (pocosins) are a rare natural community type along the North Landing River that are only maintained and prevented from succeeding to wetland pine-hardwood forest by periodic fire. Wildlife habitat required by animals that prefer early successional stages (fields, meadows, low-shrubs) is often best maintained by prescribed burning.

figure 9

figure 10

figure 11

figure 12

Invasive Species Control

An increasing number of exotic or otherwise alien species of plants and animals are invading and taking over native habitats, both terrestrial and aquatic. Some invasions are more manageable than others. Invasive plants are often a manageable pest for resource managers, especially in urban or populated regions where soil disturbance is or has been frequent. Efforts to return former agricultural fields and prior developed lands will very likely involve a broad set of invasive species management problems. However, much technology adapted from weed science and a broad assortment of approved techniques including judicious herbicide applications is available to assist such efforts.

In some cases, management or control of invasive animals may be necessary. In these cases, appropriate resources such as the Virginia Department of Game and Inland Fisheries, the U.S. Fish and Wildlife Service, the Virginia Department of Agriculture and Consumer Services, and the Virginia Department of Conservation and Recreation should be consulted.

Re-vegetation

Methods for reestablishing natural vegetation in hydrologically restored portions of conservation corridors are relatively well-known. Foresters, wildlife managers, natural area managers, and soil conservationists have developed reliable techniques for establishing trees, shrubs, native warm season grasses, and wetlands vegetation. Availability of local seed sources remains a challenge, although plant material and seed for a wide assortment of native species is generally available. It should be noted that in some cases, appropriate native seed sources may still be available within viable soil seedbanks. This document is a plan for the future, and the role of time and natural succession cannot be disregarded. Indeed, the natural succession of vegetation, ecological communities, and land use must be considered. For additional information, see the multiple benefit conservation strategy – southern watershed management plan (LandMark Design Group 2000).

Habitat Creation

Habitat can be created as a mitigation requirement. Although this type of mitigation is less preferable than habitat preservation or habitat restoration, it may have beneficial results as long as several conditions are met. One such condition is that the created habitat be located directly adjacent to an existing, functioning ecosystem, rather than disjunct. The probability for a successful creation is much higher when the created habitat can recruit species through dispersal and emigration from functioning, established habitat. Another preferred condition of habitat creation is to use soil previously removed from nearby areas. These soils would have an existing seedbank of local indigenous species, enhancing chances for success. Restoration of hydrology, and the assimilation of that restored hydrology into the adjacent functioning natural area is another condition that would augment possibilities for successful habitat creation.

Habitat Restoration

Habitat restoration as a mitigation technique will produce the most successful results when restored areas are located adjacent to functioning, established habitat, and when the restored areas are sufficiently large. Restoration techniques include, but are not limited to, restoration of hydrology by removing, or blocking ditches, or re-directing water, and planting of native vegetation. For additional information, see the Multiple Benefit Conservation Strategy – Southern Watershed Management Plan (LandMark Design Group 2000).

Mitigation Banks

If managed appropriately, mitigation banks can be highly effective tools of conservation. Mitigation banks are sometimes portions of a natural, functioning ecosystem, and are sometimes lands in the process of being restored, or a mix of the two. These endeavors often have very successful results, especially when the bank is located within, or adjacent to an existing natural, functioning ecosystem.

Wildlife Management

While much remains to be discovered about wildlife management in conservation corridors, one expected challenge will be to develop workable techniques for controlling populations of species such as whitetail deer and nutria. Lessons from many urban interface areas of the U.S. demonstrate that whitetail deer populations, in the absence of large predators and without consistent pressure from sport hunting, will expand at undesirable rates and reach unmanageable densities. Automobile collisions involving deer plus other unwanted deer-human interactions in suburban settings will occur. Thus, it will be necessary and prudent to learn from the experience of other localities and develop strategies in advance for dealing with this potential problem.

In addition to whitetail deer, there are many other wildlife species in the SWA that will benefit from conservation corridors including migratory songbirds, wading birds, American black bear, red and gray fox, raccoon, bobcat, small rodents and insectivores, amphibians, reptiles, butterflies, dragonflies, and damselflies (American Wildlands 2000; Burbrink *et al.* 1998; Schaefer and Brown 1992; Walker and Craighead 1997).

The American black bear (*Ursus americanus*) is the largest terrestrial mammal in Virginia, and is found in relatively high numbers in the SWA. While black bear movement studies have not been completed in the SWA, bear movements in Florida and Louisiana have been well documented with studies indicating that bear do utilize corridors. However, bears are adaptable and use various types of habitat. Bear movements were documented through heavily vegetated ditches, early successional fields, and woodlots. In the absence of humans, bears were also documented moving fairly long distances through open agricultural (soybean) fields (Pelton, pers. comm.). Corridor width has been shown to be less important than other parameters such as type and density of vegetation, human presence, length of corridor, and natural areas connected by the corridors (Lindenmayer 1992; Pelton, pers. comm.; Vaughan, pers. comm.). Corridors that are large enough to be effective for supporting movements of black bears are also likely to be effective for many other species.

Presently, a black bear movement study is underway in the SWA and the Great Dismal Swamp (Vaughan, pers. comm.) to determine which areas local bears choose to move through, how often they move, and which animals are moving. Results of this study will assist in refining wildlife management considerations for future protected corridor lands, in siting actual corridor placements, and in determining alternative uses. The Virginia Department of Game and Inland Fisheries is presently finalizing a Comprehensive Management Plan for Black Bears in Virginia (Pelton, pers. comm.), to be completed in early 2001. Bear and other corridor lands wildlife habitat management considerations should be coordinated with this agency.

Forest Management

Many silvicultural activities are compatible with management objectives for conservation corridors in the SWA. Reforestation of former agricultural fields using both artificial (planting) and natural techniques will be needed to establish desired vegetative conditions on conservation lands within designated corridors. Site preparation and soil conditioning may also be required, especially on lands

that have been heavily trafficked, that were in prior non-forest uses, or both. Economic returns from sound harvesting practices of forest products will be an essential incentive promoting continued forest cover, land stewardship, and reinvestment in forest management in portions of the proposed conservation corridor lands. A number of harvesting and stand establishment methods are compatible with the habitat requirements of many wildlife and plant species, and with the need to protect water quality. Combining forest and wildlife management techniques (for example, thinning followed by burning) is one effective approach for providing multiple benefits and increasing habitat diversity of the SWA while still focusing on commodity production. Use of Best Management Practices, managing for mixed-species stands, and promoting the forest stewardship ethic are among the many approaches available that will enhance values provided by managed forest lands within conservation corridors.

Considerations for the Future

Long-term planning scenarios in coastal regions involve a variety of important considerations. Coastal landscapes are dynamic and constantly influenced by sometimes harsh physical forces. They also have many amenities and so attract large numbers of people. Thus, developing coastal communities are subject to vexing management issues. Hurricanes and other severe coastal storms, land subsidence associated with groundwater withdrawals, and sea-level rise are all processes which are difficult to predict, improbable to deter, and result in profound consequences for coastal populations.

Ocean inlet formation. The closest link of Back Bay to the Atlantic Ocean is currently Oregon Inlet in North Carolina, lying 60 miles south of the state line. Historically, several inlets have opened and closed along the barrier spit that separates Back Bay from the Atlantic (Priest and Dewing 1991.) The inlet closest to Back Bay was Old Currituck Inlet, located at the present-day state line. This inlet opened in 1650 and closed in 1729. Just to the south, the New Currituck Inlet opened in 1713 and closed in 1828. Still farther south, Caffey's Inlet opened in 1798 and closed in 1812. Throughout this time there were a number of overwashes. Since the 1930's, overwashes have been infrequent with the last one occurring in 1962 during the Ash Wednesday storm (Priest and Dewing 1991).

The opening and closing of inlets to Back Bay, Currituck Sound, and the Albemarle/Pamlico Sound is a dynamic process. Shoreline stabilization and construction activities by humans may have altered the natural regime of inlet formation, but the probability of such occurrences *sometime* in the future remains 100 percent. The SWA's location in the mid-Atlantic stretch of the East Coast makes it an eventual target for a direct hurricane hit. Certain physiographic characteristics (low elevation, narrow sand ridges, etc.) make a future breach more likely at some locations than at others. Inlet formation would result in the "re-salination" of Back Bay, perhaps including the lower portions of the North Landing and Northwest Rivers. Accompanying inlet-opening could be effects such as loss of land area due to tidal flooding of lowlands and increased erosion from tidal currents. While such observations may seem speculative, it is prudent to note that the SWA lies in a "hurricane-vulnerable" area. Wise long-term land use planning must take this simple fact into account.

Subsidence. Subsidence – the gradual sinking of land – is occurring to some extent in the SWA. This process is most often caused by extraction of groundwater, oil, or natural gas as well as by the weight of sediment loads in an historic river delta. In parts of southeast Virginia, subsidence is thought to be occurring due to the effects of a bolide (meteor) impact and crater formation approximately 35 million years ago (Poag 2000). Subsequent regional geological changes include disrupted coastal aquifers and ground instability, which are likely contributing to land subsidence and sea level rise in parts of the SWA.

Sea level rise. Sea level rise at the confluence of the lower James River and Chesapeake Bay (on the rim of the bolide impact crater) is higher than average, estimated at approximately 3.5 mm/year, while global sea level rise is estimated at approximately 1-2 mm/year (USGS 2000). While sea level rise may seem to be of little significance to much of the population in the United States, in the nation's coastal areas and especially in Virginia's SWA, it is an inevitability that must be taken into consideration with long-term planning and contingencies. Indeed, the location of the SWA with regards to hurricane vulnerability, combined with the certainty of sea-level rise and subsidence makes long-term planning for this area of great importance.

Planning initiatives. At the present time, several other planning initiatives are underway in the SWA. The Virginia Chapter of The Nature Conservancy is conducting a conservation and protection planning initiative for the Green Sea Wetlands in the City of Chesapeake. Beginning in 2001, the U.S. Fish and Wildlife Service has plans to extend Comprehensive Conservation Planning initiatives into Virginia by initiating this process on the Back Bay NWR. Comprehensive Conservation Planning (called for by the 1997 Refuge Improvement Act), will examine every aspect of the Back Bay NWR program from management activities to biological monitoring and long-term goals. Projects such as these, along with ongoing research and management plans in progress by various land managers in Chesapeake and Virginia Beach (The Nature Conservancy 2000b; VDCR 2001; VDGIF 2000) will provide useful information for long-term conservation planning in the SWA.

The Department of Conservation and Recreation's Division of Natural Heritage, with funding from the U.S. Environmental Protection Agency, completed a project entitled, *Development of a Comprehensive GIS Database for the North Landing/Northwest Rivers Wetland Ecosystem.* A major focus of the project was development and mapping of a vegetation classification scheme. The community classification is described in detail in DCR-DNH Technical Report 98-9, June 1998, *Comparative Wetlands Ecology Study of the Great Dismal Swamp, Northwest River, and North Landing River in Virginia*. Fine-scaled mapping of natural communities was originally intended for both the Northwest River and the North Landing River wetlands, but funding constraints limited detailed mapping to Northwest River communities. The map produced for this project (Appendix G) is a valuable management tool, and provides considerable opportunity for SWAMP partners to prioritize wetland types for protection and restoration. The utility of this classification would be considerably expanded by extending mapping efforts to North Landing River, Back Bay, and additional wetlands within the SWA.

PROTECTION METHODS

A variety of tools and approaches are available to facilitate the protection of natural areas and open-space. Methods can be tailored to different conservation needs and specific landowner situations and include voluntary protection and management agreements, purchase of development rights, conservation easements, and fee simple acquisition.

Protection of Private Lands

Virginia Registry of Natural Areas. Natural area registry with DCR is a protection tool which involves a voluntary commitment by the landowner to protect a site. No rights to the land are given by the owner, and permanent natural area protection does not occur. The Natural Area Registry program encourages landowners of significant natural areas throughout Virginia to voluntarily protect resources on their land to the best of their ability. Landowners who participate in the program agree to inform DCR of any potential threats to resources or other changes, such as intent to sell the property. Aside from being rewarded with the pride of owning and conserving an important piece of

Virginia's natural heritage, the landowner receives a plaque recognizing the significance of their property and their effort in conserving it. Moreover, the landowner may receive management advice and assistance from professional natural area stewardship staff, if they so desire. Registry is an option available to both public and private landowners and may be used alone or in conjunction with another protection tool such as a management agreement.

Management agreements. This tool is an option for landowners who wish to manage their land to protect its biodiversity values but have no immediate desire to sell their property or encumber the land with an easement. A management agreement is a legal agreement that permits prescribed management activities by another organization or agency, but does not provide permanent protection. Under this option, the landowner and the management agency or organization will prepare a mutually acceptable agreement that clearly states management objectives, schedules, and responsibilities. These agreements fulfill specific management goals for a natural area, at least on a temporary basis, while meeting individual needs of the landowner.

Open space and conservation easements. Easements are legally enforceable agreements between a landowner and a government agency or conservation organization that place restrictions on present and future uses of land. State agencies and local governments can hold easements, or property, under the provisions of the Open Space Land Act (*Code of Virginia* 10.1-1700 *et seq*.). The Virginia Outdoors Foundation, which was created to accept and hold gifts of open space land, also accepts easements (*Code of Virginia* 10.1-1800 *et seq*.). Non-profit organizations can hold conservation easements under the provisions of the Virginia Conservation Easement Act (*Code of Virginia* 10.1-1009 *et seq*.). An easement can run for a term of years or can be perpetual, observed by present and all future owners of the land. Restrictive terms of an easement are entirely negotiable between the parties. Present and future landowners may continue to enjoy many uses of the property while conservation goals for the site are met. Landowners who sell or donate easements may also receive financial benefits such as a reduction of federal estate taxes and Virginia inheritance taxes, a reduction of real estate assessment values, and entitlement to a charitable deduction for state and federal income tax purposes.

A landowner that makes a gift of a conservation easement or gift of a fee-simple interest in land to a public conservation agency or private conservation group may be eligible for a state tax credit for that gift. The donor of the qualifying gift can use a portion of the value of that gift as a state tax credit to offset the state income taxes that the landowner might owe the Commonwealth of Virginia (*Code of Virginia,* Section 58.1-510 through 513). The tax credit can be claimed for an amount equal to 50% of the fair market value of the gift.

If a landowner sells land or sells an easement on land that will be used for open space for at least thirty years there is a new law that allows the landowner to avoid any state capital tax on the sale (*Code of Virginia*, Sections 58.1 – 322 and 58.1 – 402). Therefore, a landowner will receive a greater financial return after taxes for a sale of property, or an interest in property for conservation purposes than for development or other purposes.

Protection of Public and Private Lands

Natural area dedication. Natural area dedication provides legal protection for parcels on which the landowner restricts future uses of a property for the purpose of preserving the land in its natural state. Dedication of a property places it in the Virginia Natural Areas Preserve (NAP) system managed by DCR. This protection option is available to private landowners, state agencies, and other public bodies excepting the federal government. With natural area dedication, the landowner retains ownership rights and the right to sell or transfer the property, but relinquishes the right to use the land

in ways that are inappropriate for the conservation goals set by DCR. In effect, Natural Area Dedication is a specific type of easement and the landowner may receive the same financial benefits as in the easement option. Only lands of the highest ecological significance qualify for Natural Area Dedication.

A legal deed of Dedication is prepared which states the purpose of the dedication and future permitted and/or prohibited activities allowed. A Natural Area Management Plan is prepared by DCR-DNH. Dedicated NAPs are managed following DCR's guidelines for management of NAPs.

Acquisition. Acquisition includes the outright sale of all or a portion of the rights to property from a willing buyer to a willing seller. Mitigation banks, land trusts, private organizations, state, and federal agencies all use various forms of acquisition from time to time.

Research natural areas / special management areas. Legal or administrative designations such as Research Natural Areas (RNA) or Special Management Areas (SMA) are important for protecting biologically significant areas on federally owned lands.

Inclusion as part of a mitigation strategy. If mitigation lands are located such that inclusion with an existing protected natural area is ecologically sound, and if restoration or creation management has been successful; these lands could be included in, or added onto protected lands. Subsequently, if the lands meet certain other criteria, the areas could be legally dedicated or permanently protected in some other way.

Programs and Funding Sources

A wide variety of funding sources and programs including grants and financial incentive programs exist which could potentially fund efforts towards conservation, protection, restoration, habitat enhancement, and other initiatives. Some of these programs and sources include federal grants such as the North American Wetlands Conservation grant program of the U.S. Fish and Wildlife Service, wetland grants from the North American Wetlands Conservation Council, and state grants such as the Virginia Land Conservation Foundation (VLCF), Virginia Forest Legacy Program, Virginia Beach Agricultural Reserve Program, Conservation Reserve Enhancement Program, Native Plant Conservation Initiative, Clean Water Act Nonpoint Source Grants, Partners for Fish and Wildlife Program, Wildlife Habitat Incentives Program, Corporate Wetland Restoration Partnership, Environmental Quality Incentives Program, and Pathways to Nature. Brief descriptions of two of these follow.

Virginia Land Conservation Foundation. The VLCF uses state funds appropriated biennially by the General Assembly for fee-simple acquisition or for the purchase of conservation easements in order to protect lands in four categories: open space and parks, natural areas, historic areas, and farmland and forest preservation. Individual grant applications are submitted by local governments and non-profits from throughout the state. VLCF has flexibility to provide funding for needed projects anywhere in Virginia, meeting conservation needs in both rural and urban areas. State funding for VLCF was first committed in 1999 with $1.75 million received.

Forest legacy. The U.S. Forest Service Forest Legacy Program assists state governments in identifying and protecting important private forest tracts. The program promotes the "Working Forestlands" concept into general land conservation efforts and focuses on the ideal that diverse, well managed forests provide the most public benefits and are worthy of protection from economic pressure for development. Thus, Forest Legacy aims to protect and conserve important forests that are threatened by conversion to non-forest uses. The program, which began in Virginia in January

2001, is administered through the Virginia Department of Forestry and will provide funding primarily to purchase conservation easements to influence disposition of important forestland while continuing private ownership.

PROTECTION PRIORITIES

In 1989, The Nature Conservancy and DCR began protection efforts that, to date, have resulted in the acquisition of 20 tracts on the North Landing River and six on the Northwest River. Additional tracts owned by the U.S. Army Corps of Engineers, the City of Virginia Beach, the City of Chesapeake, Virginia Department of Game and Inland Fisheries, and the U.S. Fish and Wildlife Service add to the lands along these rivers and in Back Bay receiving at least some level of environmental protection (Figure 5). Appendix H lists pertinent federal and state natural resource laws that also afford some protection to these areas.

Protection of individual sites containing significant elements of biodiversity is a good first step toward conservation of critical habitats in the region. However, it is an inescapable fact that ecosystem-level conservation requires an approach that emphasizes linkage of natural areas and the viability of conservation sites within a larger landscape context. One of the most compelling aspects of the watersheds comprising portions of the Cities of Chesapeake and Virginia Beach, is the remaining interdigitated mosaic of large, diverse, and undisturbed wetland habitats that result from the contiguity of the three systems. Forested, non-riverine wetlands at the head of the Northwest River abut the vast wetlands of the Great Dismal Swamp National Wildlife Refuge (Figure 1). Unfortunately, a heavily traveled road, U.S. Route 17 and the Dismal Swamp Canal / Intracoastal Waterway prevent the two forested areas from merging, but their proximity still provides a linkage that is used by many mobile animals and is particularly valuable to migratory songbirds. Forested wetlands and marshes continuously line the Northwest River to its confluence with Currituck Sound at Tull Bay, then continue to the east and north to the mouth of the North Landing River. From there, large wetlands continue almost unbroken to the North Landing headwaters in the vicinity of Gum Swamp and North Landing. Conservation sites and adjacent lands identified by DCR, DNH scientists have been prioritized by watershed, to facilitate immediate (near-term) protection, restoration, mitigation, and conservation efforts (Figure 13). Identification of these lands does not imply that other sites or lands are unimportant, merely that these areas are critically important to meeting goals of the SWAMP. Prioritization of sites included an assessment of: site location, size, contribution to SWAMP goals, management needs, vulnerability and immediate or long-term threats, ecological significance, and interviews with inventory scientists or review of technical reports and field notes.

Northwest River watershed: The Northwest River basin comprises the largest and most important natural area within the City of Chesapeake. The river is a major contributor to the Currituck Sound, and ultimately the Albemarle/Pamlico estuarine system. In Virginia, it is the only corridor connecting flora and fauna of the Great Dismal Swamp to original Swamp remnants, and to other riverine systems. Large areas here are partially to entirely unprotected and are critical to ensuring long-term conservation of lands necessary to maintain the natural corridors described above.

Priorities: Protection efforts that contribute to conservation of the following sites and adjacent lands should be considered high priority. Land within the site boundaries, as well as land adjacent to the boundaries (Figure 13) is important to protect, restore or enhance. Most of these sites contribute significantly to creation of potential corridors discussed in this conservation plan, and as such, make significant contributions to achievement of overall SWAMP goals. Specific site conservation plans for the sites listed below can be found in Appendix C.

Sites: Headwaters
Smith Ridge
NSGA Northwest
Middle Section
Smith Creek
Southwestern Marshes

North Landing River watershed: This watershed merits a very high level of protection. In addition to serving as a recreational, scenic, and educational asset for residents of the City of Virginia Beach and surrounding areas, the North Landing River watershed also facilitates flood protection for the City during storm events, it filters and stabilizes surface water for a large portion of the City, and it supports a diverse array of plants, animals, and ecological communities. The North Landing River is also a major tributary to the Currituck Sound, and ultimately, the Albemarle/Pamlico Estuarine system.

Priorities: Protection efforts that contribute to the conservation of the following sites and adjacent lands should be considered high priority. Most of these sites contribute significantly to the potential corridors discussed in this report. Specific site conservation plans for the sites listed below can be found in Appendix D.

Sites: Gum Swamp
North Landing River Pocosins
Eastern Marshes
Southern Marshes

Back Bay watershed: This watershed also merits a high level of protection as it also supports a diverse array of rare plants, animals, and ecological communities. Back Bay serves as a recreational, scenic and educational asset for residents of the City of Virginia Beach, facilitates flood protection for the City during storm events and hurricane season, and is a major tributary to the Currituck Sound, and ultimately, the Albemarle/Pamlico Estuarine system.

Priorities: Protection efforts that contribute to the conservation of the following Back Bay sites and adjacent lands (Figure 13) should be considered high priority. Most of these sites contribute significantly to the potential corridors discussed in this report. Specific site conservation plans for the sites listed below can be found in Appendix E.

Sites: Black Gut
Back Bay National Wildlife Refuge
Nawney Creek
Muddy Creek
False Cape State Park

SUMMARY AND RECOMMENDATIONS

Communities across the country are grappling with growth, and the lessons of unplanned urban expansion are evident around us. New efforts begun now, such as a conservation corridor initiative, could help the Cities of Chesapeake and Virginia Beach to retain desirable levels of open space and greenways, protect water quality, wildlife habitat, and rare forms of life in the process. A century ago, Theodore Roosevelt helped set this nation on the path of conservation. He reminded us that "Our responsibilities to the coming millions are like that of parents to children. In wasting our resources, we are wronging our descendants." Conservation is not a new idea; but its application in areas of rapid growth has never been more timely and needed than today.

figure 13

The use of conservation corridors represents only part of an integrated ecosystem and natural resource protection strategy. Many effective resource conservation techniques are currently promoted through programs conducted by agencies such as the USDA Natural Resource Conservation Service, Virginia Tech-Cooperative Extension, DCR-Division of Soil and Water Conservation, Virginia Department of Environmental Quality, Virginia Department of Forestry, Virginia Department of Game and Inland Fisheries, and the Cities of Chesapeake and Virginia Beach.

While effective in their own right, most existing conservation programs do not address the need for conceptualizing and designing a landscape preferred by citizens and yielding optimum long-term natural resource and open-space benefits. Such an initiative can and must derive from the localities themselves, expressing the views and wishes of local residents, businesses, and government entities. Successfully managing growth means empowering citizens and leaders to make informed decisions about whether or not it is important and desirable to conserve open space and natural resources. This should be done in advance of sprawl and while there is still time to protect and retain the best of what is left. Such success will only be attained if ideas, options, and potential outcomes are presented and debated in an open public process.

Expanded conservation corridor options will be complex to implement, as they cross locality and political lines, and involve a variety of legal, regulatory, and social issues. While this plan does not provide a specific framework or blueprint for corridor implementation, some suggested land protection approaches have been put forward. Fair market compensation for property or development use rights from willing sellers is the only means by which privately owned lands should be obtained for conservation purposes. In the end, societal and political processes will largely determine whether or not such planned efforts at retention of open space and natural resources will come to fruition.

LITERATURE CITED AND PERTINENT REFERENCES

Adams, V. and B. Mundy. 1991. The valuation of high-amenity natural land. Appraisal Journal January: 48-53.

American Wildlands. 2000. Corridors of life project. (http://www.wildlands.org/corridor/corridor.html) September 2000.

Andren, H. 1994. Effects of habitat fragmentation and mammals in landscapes with different proportions of suitable habitat: a review. Oikos: A Journal of Ecology 71(3).

Atkinson, G., and K. Hamilton. 1996. Accounting for progress: indicators for sustainable development. Environment 38(7): 16.

Bales, J. D. and S. C. Skrobialowski. 1993. Salt transport in a tidal canal, West Neck Creek, Virginia. Pages 1422-1427 in H.W. Shen, S.T. Su, and F. Wen, eds., Hydraulic Engineering >93. American Society of Civil Engineers.

Belden, A., Jr. 1993. An inventory of rare, threatened, and endangered plant species of Naval Security Group Activity, Northwest, Department of the Navy, Chesapeake, Virginia. Nat. Heritage Tech. Rep. 93-1. Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 19 pp.

Belden, A., Jr. 1996. A natural heritage inventory of the Southeastern Public Service Authority of Virginia regional landfill proposed expansion site. Nat. Heritage Tech. Rep. 96-21. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 37 pp.

Belden, A., Jr., ed. 1998. Natural heritage resources of Virginia: rare vascular plants. Natural Heritage Tech. Rep. 98-2. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 36 pp. plus appendices.

Belnap, J. 1998. Choosing indicators of natural resource condition: a case study in Arches National Park, Utah, USA. Environmental Management 22:635-642.

Bertstrom, J., J. Stroll, J. Titre, and V. Write. 1990. Economic value of wetlands-based recreation. Ecological Economics 2:129-147.

Biondo, B. 2000. Stand by your land. Nature Conservancy, Sept/Oct 2000. Pages 26-33.

Blum, E. Making biodiversity conservation profitable: a case study of the Merck/Inbio agreement. Environment 35(4): 16-20, 38-45.

Boyle, K. J. and R. C. Bishop. 1987. Valuing wildlife in benefit-cost analysis: a case study involving endangered species. Water Resources Research 23: 943-950.

Brabec, E. 1992. On the value of open spaces. Scenic America – Technical Information Series 1(2) 8pp.

Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Press, New York. 596 pp.
Brown, P. H., and C. L. Lant. The effect of wetland mitigation banking on the achievement of no-net-loss. Environmental Management 23(3):333-345.

Burbrink, F. T., C. A. Phillips, E. J. Heske. 1998. A riparian zone in southern Illinois as a potential dispersal corridor for reptiles and amphibians. Biological Conservation 86: 107-115.

Cabe, P. R. 1984. *Trillium pusillum* Michx. in Virginia: a study of systematics and reproductive ecology. Honors Thesis, The College of William and Mary, Williamsburg, Va. 69 pp.

City of Raleigh, NC. 2000. Neuse River Corridor Master Plan (http://www.treklite.com/neuse/p4corri.htm) on-line version 09/16/2000.

City of New York, Parks and Recreation. 2000. The Greenbelt History, The Greenbelt Conservancy (http:nycparks.completeinet.net/) on-line version 09/18/2000.

Clampitt, C. A., J. C. Ludwig, T. J. Rawinski, and C. A. Pague. 1993. A natural Areas Inventory of the City of Virginia Beach, Virginia. Natural Heritage Technical Report #93-14. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond. 35 pp + appendices.

Clark, K.H. 1997. Southern watersheds common reed project, final report. Nat. Heritage Tech. Rep. 96-19. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 35 pp.

Clark, K. H. and J. L. Potter. 1995. North Landing River natural area preserve resource management plan, first edition. Nat. Heritage Tech. Rep. 95-9, Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 164 pp.

Collinge, S. K. 1996. Ecological consequences of habitat fragmentation: implications for landscape architecture and planning. Landscape and Urban Planning 36(1).

Copeland, B. J., R. G. Hodson, S. R. Riggs, and J. E. Easley, Jr. 1983. The ecology of Albemarle Sound, North Carolina: an estuarine profile. U.S. Fish and Wildlife Service, Div. of Biological Services, Pub. FWS/OBS-83/01. Washington, D.C.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79/31. 103 pp.

Crance, C. and D. Draper. 1996. Socially cooperative choices: an approach to achieving resource sustainability in the coastal zone. Environmental Management 20:175-184.

Dabel, C. V. and F. P. Day. 1977. Structural comparison of four plant communities in the Great Dismal Swamp, Virginia. Bull. Torrey Bot. Club 104:352-360.

Daily, G. C., S. Alexander, P. R. Ehrlich, L. Goulder, J. Lubchenco, P. A. Matson, H. A. Mooney, S. Postel, S. H. Schneider, D. Tilman, G. M. Woodwell. 2000. Ecosystem services: benefits supplied to human societies by natural ecosystems. Ecological Society of America – Issues in Ecology 16 pp.

Daniel, C. C. III. 1977. Digital Flow Model of the Chowan River Estuary, North Carolina. U.S. Geological Survey Water Resources Investigations 77-63.

Dardeau, M. R., R. F. Modlin, W. W. Schroeder, and J. P. Stout. 1992. Estuaries. Pages 614-744 in C. T. Hackney, S. M. Adams, and W. H. Martin. Biodiversity of the southeastern United States: aquatic communities. John Wiley & Sons, New York.

Dean, G. W. 1969. Forests and forestry in the Dismal Swamp. Virginia J. Sci. 20:166-173.

Dixon, J. A. and P. B. Sherman. 1990. Economics of Protected Areas: A New Look at Benefits and Costs. Island Press, Washington, DC. 234 pp.

Doumlele, D. G. 1976. City of Virginia Beach marsh inventory, Vol 1. North Landing River and tributaries. Special Rep. No. 118, Virginia Institute of Marine Science, Gloucester Point, VA. 49 pp.

Downes, S. J., K. A. Handasyde, and M. A. Elgar. 1997. The use of corridors by mammals in fragmented Australian eucalyptus forests. Conservation Biology 11(3): 718-726.

Erdle, S. Y. and J. F. Pagels. 1995. Observations on *Sorex longirostris* (Mammalia: Soricidae) and associates in eastern portions of the historical Great Dismal Swamp. Banisteria 6:17-23.

Erdle, S. Y., M. A. Donoff, C. A. Caljouw, and L. R. Smith. 1994. Conservation planning for the management and protection of natural areas in the Albemarle-Pamlico estuarine study area of Virginia. Nat. Heritage Tech. Rep. 94-9. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 92 pp. plus appendices.

Erdle, S. Y., M. A. Donoff, L. R. Smith, C. A. Caljouw, and H. C. Bernick, III. 1994. Conservation planning for the management and protection of natural areas in the City of Virginia Beach, Virginia. Nat. Heritage Tech. Rep. 94-12. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 117 pp. + appendices.

Facazio, M., C. Caljouw, G. Speiran, and T. Yanosky. 1998. Assessment of hydrologic relations of wetlands to surrounding areas in the North Landing River Natural Area Preserve. U.S. Environmental Protection Agency. Virginia Dept. of Conservation and Recreation, Division of Natural Heritage. Natural Heritage Technical Report #98-15, Richmond, VA. 20 pp + appendices.

Fausold, C. J., and R. J. Lilieholm. 1999. The economic value of open space: a review and synthesis. Environmental Management 23:307-320.

Fearnside, P. M. 1997. Environmental services as a strategy for sustainable development in rural Amazonia. Ecological Economics 20(1): 53-70.

Fernandez, L. 1999. An analysis of economic incentives in wetlands policies addressing biodiversity. The Science of the Total Environment 240: 107-122.

Fernandez, L. and L. Karp. 1998. Restoring wetlands through wetlands mitigation banks. Environmental and Resource Economics 13(3): 323-344.

Fleming, G. P., P. P. Coulling, D. P. Walton, K. M. McCoy, and M. R. Parrish. 2001. The natural communities of Virginia: classification of ecological community groups. First approximation. Natural Heritage Technical Report 01-1. Virginia Department of Conservation and Recreation, Division of Natural Heritage, Richmond, VA. Unpublished report. 76 pp.

Fleming, G. P., C. S. Hobson, and B. Carmean. 1998. Natural Heritage inventory of the City of Chesapeake, Virginia: conservation priorities, significant natural communities, and rare species. Natural Heritage Technical Rpt. 98-10, Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 97 pp plus appendices.

Fleming, G. P. and W. H. Moorhead. 1998. Comparative wetlands ecology study of the Great Dismal Swamp, Northwest River, and North Landing River in Virginia. Natural Heritage Technical Rep. 98-9. Virginia Dept. of Conservation and Recreation, Division of Natural Heritage, Richmond. 181 pp. plus appendices.

Fernald, M. L. 1942. The seventh century of additions to the flora of Virginia. Rhodora 44: 341-484.

Fleury, A. M. and R. D. Brown. 1997. A framework for the design of wildlife conservation corridors (with specific application to southwestern Ontario). Landscape and Urban Planning 37(3).

Francis, M., L. Cashdan, and L. Paxson. 1984. Community open spaces: greening neighborhoods through community action and land conservation. Island Press, Washington, DC 250 pp.

Frost, C. C. 1989. History and status of remnant pocosin, canebrake white cedar wetlands in Virginia. Report to Virginia Natural Heritage Program.

Frost, C. C. 1995. Presettlement fire regimes in southeastern marshes, peatlands, and swamps. Pages 39-60 in S. I. Cerulean and R. T. Engstrom, eds. Proceedings 19th Tall Timbers Fire Ecology Conference, Tall Timbers Research Station, Tallahassee, FL.

Frost, C. C., H. E. LeGrand, Jr., and R. E. Schneider. 1990. Regional inventory for critical natural areas, wetland ecosystems, and endangered species habitats of the Albemarle-Pamlico estuarine region: phase 1. Albemarle-Pamlico Study Rep. 90-01, Raleigh, NC. 441 pp.

Godfrey, R. K. and J. W. Wooten. 1981. Aquatic and wetland plants of southeastern United States, dicotyledons. University of Georgia Press, Athens, Ga. 933 pp.

Goldsmith, V., ed. 1977. Coastal processes and resulting forms of sediment accumulation, Currituck Spit, Virginia-North Carolina. SRAMSOE No. 143, Virginia Institute of Marine Science, Gloucester Point, VA.

Greenways Incorporated. 2000. Open space projects, Greenways Incorporated. (http://www.greennways.com/pages/openspace.html) on line version 09/21/2000.

Gresswell, R. E. and W. J. Liss. 1995. Values associated with management of Yellowstone Cutthroat Trout in Yellowstone National Park. Conservation Biology 9(1): 159-165.

Hackney, C. T., S. M. Adams, and W. H. Martin (eds). 1992. Biodiversity of the Southeastern United States: Aquatic Communities. John Wiley & Sons, Inc. New York. 779 pp.

Haddad, N. M. 1999. Corridor use predicted from behaviors at habitat boundaries. American Naturalist, 153:215-227.

Hampton Roads Planning District Commission. 2001. Census tract populations in the southern watershed area of Chesapeake - 1970, 1980, 1990. (Summarized data)

Hatch, D. R., J. E. Belshan, S. M. Lantz, G. R. Swecker, and D. E. Starner. 1985. Soil survey of City of Virginia Beach, Virginia. U.S.D.A. Soil Conservation Service in cooperation with Virginia Polytechnic Institute and State University. U.S. Government Printing Office. 131 pp. plus maps.

Heffernan, K. E. 2000. Northwest River Natural Area Preserve Resource Management Plan, DRAFT. Natural Heritage Technical Document. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond, VA 57 pp + appendices.

Henry, E. F. 1970. Soils of the Dismal Swamp of Virginia. Virginia J. Sci. 21:41-46.

Henry, E. F., J. Chudoba, and H. C. Porter. 1959. Soil survey, Norfolk County, Virginia. USDA Series 1953, No. 5. U.S.D.A. Soil Conservation Service in cooperation with Virginia Agricultural Experiment Station, Washington, D.C.: U.S. Government Printing Office. 53 pp. plus maps.

Hobson, C. S. In press. Bat records from southeastern Virginia, including a new resident species, *Myotis austroriparius* (Chiroptera: Vespertilionidae). Brimleyana 27.

Huxel, G. R. and A. Hastings. 1999. Habitat loss, fragmentation, and restoration. Restoration Ecology 7(3).

Holdren, J. P., and P. R. Ehrlich. 1974. Human population and the global environment. American Scientist 62: 282-292.

Hyman, J. B. and S. G. Leibowitz. 2000. A general framework for prioritizing land units for ecological protection and restoration. Environmental Management 25:23-35.

Indy Greenways Organization, 1999. Conservation Corridors, description and plans in the Indianapolis Greenways Master Plan. (http://www.indygreenways.org/corridors/corridors/htm) on-line version 09/16/2000.

Keys, J. E., C.A. Carpenter, S. L. Hooks, F. G. Koenig, W. H. McNab, W. E. Russell, and M. L. Smith. 1995. Ecological units of the eastern United States - first Approximation. Tech. Pub. R8-TP21, U.S.D.A. Forest Service, Atlanta.

Kirby, K. J. 1993. Wetlands not wastelands. Scenic America – Technical Information Series 1(5): 8 pp.

LandMark Design Group. 2000. Multiple benefit conservation strategy - southern watershed management plan. Prepared for the Hampton Roads Planning District Commission. pp.

Leger, A. D. 1990. Refuge management: committed to the future. Pages 295-298 in H. G. Marshall and M. D. Norman, eds. Proceedings of the Back Bay Ecological Symposium, hosted by VA Marine Science Museum and sponsored by the VA Dept. of Game and Inland Fisheries, College of Sciences-Old Dominion Univ. Published by the Dept. of Biological Sciences, Old Dominion University, Norfolk, VA.

Levy, G. F. and S. W. Walker. 1979. Forest dynamics in the Dismal Swamp of Virginia. Pages 101-126 in P. W. Kirk, ed. The Great Dismal Swamp. Proc. of a symposium sponsored by Old Dominion Univ. and United Virginia Bank-Seaboard National. The University Press of Virginia, Charlottesville.

Lewis, R. R. III. 1992. Coastal ecosystems. Restoration & Management Notes 10(1): 18-20.

Lichtler, W. F. and P. N. Walker. 1979. Hydrology of the Dismal Swamp. Pages 140-168 in P.W. Kirk, ed. The Great Dismal Swamp. Proc. of a symposium sponsored by Old Dominion Univ. and United Virginia Bank-Seaboard National. The University Press of Virginia, Charlottesville.

Lindberg, K. 1996. The Economic Impacts of Ecotourism. Charles Sturt University, text of presentation, World Wide Web.

Lindenmayer, D. B. 1992. The distribution and abundance of arboreal marsupials in retained linear strips (wildlife corridors) in timber production forests. Value Adding and Silvicultural Systems Program. Report No. 9. Native Forest Research: Sept. 1992.

Lindenmeyer, D. B. and H. A. Nix. 1993. Ecological principles for the design of wildlife corridors. Conservation Biology 7(3): 627-630.

Lindsay, B. E., J. M. Halstead, and H. C. Tupper. 1992. Factors influencing the willingness-to-pay for coastal beach protection 20(3).

Lindsey, G. and G. Knaap. 1999. Willingness to pay for urban greenway projects. American Planning Journal, Summer 1999, pp 297-313.

Lowrance, R., L. S. Altier, J. D. Newbold, R. R. Schnabel, P . M. Groffman, J. M. Denver, D. L. Correll, J. W. Gilliam, J. L. Robinson, R. B. Brinsfield, K. W. Staber, W. Lucas, and A. H. Todd. 1997. Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. Environmental Management 21:687-712.

Mabey, S. E., J. M. McCann, L. J. Niles, C. Bartlett, P. Kerlinger. 1993. The neotropical migratory songbird coastal corridor study: Virginia special edition. A report of the Virginia Department of Environmental Quality to the National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resource Management. 72 pp + appendices

Macdonald, S. H. 2000. Green threads in the urban fabric. Greenways and Urban Trails (http:www.outdoorlilnk.com/amtrails/resources/greenways/GrnwyUrbanSHM.html) on line version 09/21/2000.

Machtans, C. S., M. A. Villard, and S. J. Hannon. 1996. Use of riparian buffer strips as movement corridors by forest birds. Conservation Biology 10(5): 1366-1379.

Macmillan, D. C. Cost-effectiveness analysis of woodland ecosystem restoration. Ecological Economics 27(3): 313-324.

Malakoff, D. Restored wetlands flunk real-world test. Science 280(5362): 371-372.

Mares, M. A. 1998. Tropical forest remnants: ecology, management, and conservation of fragmented communities. Journal of Wildlife Management 62(4): 1581-1583.

Marshall, H. G. 1979. Lake Drummond: with a discussion regarding its plankton composition. Pages 169-182 in P. W. Kirk, ed. The Great Dismal Swamp. Proc. of a symposium sponsored by Old Dominion Univ. and United Virginia Bank-Seaboard National. The University Press of Virginia, Charlottesville.

Marshall, H. G., and M. D. Norman (eds). 1990. Proceedings of the Back Bay symposium. Dept. of Biological Sciences, Old Dominion Univ.

McAfee, K. 1999. Selling nature to save it? Biodiversity and green developmentalism. Environment and Planning 17: 133-154.

McMahon, E. T., and S. S. Hollberg. 1999. Better models for development in the Shenandoah Valley. Valley Conservation Council and The Conservation Fund 87 pp.

Meanley, B. 1968. Notes on Dismal Swamp plants. Atlantic Nat. 23:78-82.

Meanley, B. 1969. The wild camellia and dwarf trillium in the Great Dismal Swamp. Atlantic Nat. 24: 19-20.

Metrick, A. and M. L. Weitzman. 1998. Conflicts and choices in biodiversity preservation. The Journal of Economic Perspectives 12(3): 21-34.

Miller, B., R. Reading, J. Strittholt, C. Carroll, R. Noss, M. Soule', O. Sanchez, J. Terbough, D. Brightsmith, T. Cheesman, and D. Foreman. 1998. Using focal species in the design of nature reserve networks. The Wildlands Project. Winter 1998/1999 pp 81-92

Mitchell, J. C. 1994. The reptiles of Virginia. Smithonian Institution Press, Washington and London. 352 pp.

Mitchell, J. C. and D. Schwab. 1991. Canebrake Rattlesnake (*Crotalus horridus atricaudatus* Latreille). Pages 462-464 in K. Terwilliger, ed. Virginia=s Endangered Species. Proceedings of a Symposium. McDonald Woodward Publishing Co., Blacksburg, Virginia. 672 pp.

Mixon, R. B., C. R. Bergquist, Jr., W. L. Newell, and G. H. Johnson. 1989. Geologic map and generalized cross sections of the coastal plain and adjacent parts of the piedmont, Virginia. U.S. Geological Survey, Denver, Colorado.

Moon, S. 1993. Local options for conserving natural areas. Virginia Council on the Environment, for the VA Dept. of Conservation and Recreation, Richmond, VA 18 pp.

Moore, R. H. 1992. Low-salinity backbays and lagoons. Pages 541-613 in C. T. Hackney, S. M. Adams, and W. H. Martin. Biodiversity of the southeastern United States: aquatic communities. John Wiley & Sons, New York.

Morton, J. M. and C. M. Kane. 1994. Back Bay, Virginia: A literature review and synthesis of natural resource status and trends. Funded by: Back Bay National Wildlife Refuge, Project Code 90-5109. 53 pp.

Munda, G. 1997. Environmental economics, ecological economics, and the concept of sustainable development. Environmental Values 6(2): 213-233.

Munro, J. W. 1991. Wetland restoration in the mitigation context. Restoration & Management Notes 9(2): 80-86.

Neilson, B. J. 1976. Water quality in the small coastal basins: Gloucester Point, Virginia, Special Report No. 129, *in* Applied Marine Science and Ocean Engineering, Virginia Institute of Marine Science, 139 pp.

Norman, M. D. 1990. Description of the study area. Pages 4-6 in Marshall, H.G. and M.D. Norman, eds. Proc. of the Back Bay Ecological Symposium. Old Dominion Univ., Norfolk.

Noss, R. F. 1987. Corridors in Real Landscapes: A Reply to Simberloff and Cox. Conservation Biology 1(2): 159-164.

Noss, R. F., M. A. O'Connell, and D. D. Murphy. 1997. The science of conservation planning: habitat conservation under the endangered species act. Island Press, Washington, DC. 246 pp.

Oaks, R. Q., and N. K. Coch. 1973. Post-Miocene stratigraphy and morphology, southeastern Virginia: Virginia Division of Mineral Resources, Bulletin 82.

Oaks, R. Q. and D. R. Whitehead. 1979. Geologic setting and origin of the Great Dismal Swamp, southeastern Virginia and northeastern North Carolina. Pages 1-24 in P. W. Kirk, ed. The Great Dismal Swamp. Proc. of a symposium sponsored by Old Dominion Univ. and United Virginia Bank-Seaboard National. The University Press of Virginia, Charlottesville.

O'Neill, R. V., J. R. Kahn, and C. S. Russell. 1998. Economics and ecology: the need for detente in conservation ecology. Conservation Ecology. 12(1): 1-10.

Ostlie, W. R. 1990. Element stewardship abstract for *Carex decomposita*, cypress-knee sedge. The Nature Conservancy, Arlington, VA 10 pp.

Padgett, T. M. 1991. The identification, distribution, and status of the threatened Dismal Swamp shrew (*Sorex longirostris fisheri*). M.S. Thesis. Old Dominion University, Norfolk, Va. 60 pp.

Pate J., and J. Loomis. 1997. The effect of distance on willingness to pay values: a case study of wetlands and salmon in California. Ecological Economics 20: 199-207.

Peiser, R., and G. Schwann. 1993. The private value of public open space within subdivisions. Journal of Architectural and Planning Research 10(2): 91-104.

Priest, W. I. III and S. Dewing. 1991. The marshes of Back Bay, Virginia. Pages 222-227 in Marshall, H. G. and M.D. Norman, eds. Proceedings of the Back Bay Ecological Symposium. Old Dominion Univ., Norfolk.

Pugh, D. 1994. The need for wildlife corridors. Flora and Fauna Index (http:www.nefa.org.au/nefaweb/corridor.html) 6 pp. on-line 09/16/2000

Rader, E. K. and N. H. Evans, editors. 1993. Geologic map of Virginia - expanded explanation: Virginia Division of Mineral Resources, Charlottesville. 80 pp.

Rails to Trails. 2000. Recreation Trails in Pittsburg and Western PA, Rails to Trails Conservancy. (on line - http://pittsburg)

Rawinski, T. J. and G. P. Fleming. 1993. An inventory and protection plan for southeast Virginia's critical natural areas, exemplary wetlands, and endangered species habitats. Albemarle-Pamlico Study Report. Technical Report # 93-13. Raleigh, NC 200 pp.

Rennings, K., and H Wiggering. 1997. Steps towards indicators of sustainable development: linking economic and ecological concepts. Ecological Economics 20(1): 25-36.

Rideout, R. R. and D. A. Adams. 1990. The Currituck Sound drainage basin: perceived issues and prospective management alternatives. Pages 273-285 in H. G. Marshall and M. D. Norman, eds. Proceedings of the Back Bay Ecological Symposium, hosted by VA Marine Science Museum and sponsored by the VA Dept. of Game and Inland Fisheries, College of Sciences-Old Dominion Univ. Published by the Dept. of Biological Sciences, Old Dominion University, Norfolk, VA.

Roanoke Valley Greenways, 2000. Roanoke Valley Greenways Home Page (http://www.greenways.org/) Roanoke Valley Greenways, P. O. Box 29800, Roanoke, VA 24018

Roble, S. M. 1996. Natural heritage resources of Virginia: rare animal species. Natural Heritage Technical Rept. 96-11. Virginia Dept. of Conservation and Recreation, Div. of Natural Heritage, Richmond. 23 pp. plus appendices.

Robles, M. 2000. Incentives for wildlife enhancement on midwestern farms. Environment and Agriculture Program, Institute for Agriculture and Trade Policy, Minneapolis, MN (www.iatp.org/enviroag) 42 pp.

Roe, G. F. 1978. Additions to the range of *Trillium pusillum.* Castanea 43: 187-191.

Rose, R. K. 1994. Final report of the field study to determine the presence of the federally threatened Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*) on the 69-acre Kirk property adjacent to the SPSA landfill in Suffolk, Virginia. Unpublished report submitted to the Southeastern Public Service Authority of Virginia.

Rose, R. K. and T. M. Padgett. 1991. Southeastern shrew (*Sorex longirostris fisheri* Merriam). Pages 562-564 in K. Terwilliger, ed. Virginia=s Endangered Species. Proceedings of a Symposium. McDonald Woodward Publishing Co., Blacksburg, Virginia. 672 pp.

Rose, R. K., T. M. Padgett, and C.A. Pague. 1988. Status survey of amphibians, reptiles, birds, and mammals of Naval Security Group Activity Northwest, Chesapeake, Virginia. Unpublished rep. on file with the Atlantic Division, Naval Facilities Engineering Command, Norfolk, Va. 66 pp.

Ruefenacht, B. and R. L. Knight. 1995. Influences of corridor continuity and width on survival and movement of deermice *Peromyscus maniculatus*. Biological Conservation 71(3): 269-274.

Sagoff, M. 1996. On the value of endangered and other species. Environmental Management 20: 897-911.

Schaefer, J. M. and M. T. Brown. 1992. Designing and protecting river corridors for wildlife. Rivers: studies in the science. 3(1).

Schafale, M. P. and A. S. Weakley. 1990. Classification of the natural communities of North Carolina: Third Approximation. North Carolina Dept. of Environment, Health, and Natural Resources, Raleigh.

Scott, M. J., G. R. Bilyard, S. O. Link, C. A. Ulibarri, H. E. Westerdahl, P. F. Ricci, and H. E. Seely. 1998. Valuation of ecological resources and functions. Environmental Management 22(1): 49-68.

Simpson, B. 1990. The Great Dismal: a swamp memoir. Henry Holt and Co., New York.

Siudyla, E. A., A. E. May, and D. W. Hawthorne. 1981. Ground water resources of the four cities area, Virginia (Norfolk, Virginia Beach, Portsmouth, Chesapeake). Commonwealth of Virginia, State Water Control Board, Bureau of Water Control Management. Planning Bulletin 331. 90 pp + appendices.

Slocombe, D. S. 1998. Defining goals and criteria for ecosystem-based management. Environmental Management 22:483-493.

Small, S. J. 1990. The federal tax law of conservation easements, 2nd ed. Land Trust Alliance, Alexandria, VA.

Smallwood, K. S., J. Beyea, and M. L. Morrison. 1999. Using the best scientific data for endangered species conservation. Environmental Management 24:421-435.

Stanley, D. W. 1992. Historical trends: water quality and fisheries, Albemarle-Pamlico Sounds, with emphasis on the Pamlico River estuary. University of North Carolina Sea Grant College Program Publication UNC-SG-92-04. Institute of Coastal and Marine Resources, East Carolina University, Greensville, NC. 215 pp.

Stevens, A. and W. A. Patterson, III. 1998. Millennium-long fire and vegetation histories of pocosins of southeastern Virginia. (Part of: Restoring a wetland ecosystem: protection and fire management programs for the North Landing River wetlands – Phase 1.) Virginia Department of Conservation and Recreation, Division of Natural Heritage, Technical Report #98-17, Richmond, VA. Unpublished report submitted to USDC National Oceanic and Atmospheric Administration.

Stolzenburg, W. 1991. Wildlife Corridors: The Fragment Connection. The Nature Conservancy Magazine. 4(4):18-25.

The Nature Conservancy. 2000a. The five-S framework for site conservation: a practitioner's handbook for site conservation planning and measuring conservation success. First edition. The Nature Conservancy, Conservation Science Division, March 2000.

The Nature Conservancy. 2000b. Green sea conservation planning initiative. Coordinated through the Green Sea Planning office, Norfolk, VA.

Thomas, C. D., J. K. Hill, and O. T. Lewis. 1998. Evolutionary consequences of habitat fragmentation in a localized butterfly. The Journal of Animal Ecology 67(3).

Thomas, D. S. K. and O. J. Furuseth. 1997. The realities of incorporating sustainable development into local-level planning: a case study of Davidson, North Carolina. Cities 14(4): 219-226.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1996. 1996 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

U.S. Fish and Wildlife Service. 1986. Atlas of national wetlands inventory maps, Chesapeake Bay, vol. 1, coastal plain of Virginia - western shore. Newton Corner, Massachusetts.

U.S. Fish and Wildlife Service. 1994. Dismal Swamp southeastern shrew (*Sorex longirostris fisheri*) recovery plan. Technical/advisory draft. USFWS, Hadley, Mass. 51 pp.

U. S. Geological Survey. 1997. Sampling to determine the age of ground water of pocosins of the North Landing River, Virginia. Unpublished report for the VA Department of Conservation and Recreation 10 pp.

Vicary, B. 1994. Trends in appraising conservation easements. Appraisal Journal. January: 138-143.

Virginia Department of Environmental Quality. 1995a. General report of all waterbody data: North Landing River. 27 Jan. 1995. VDEQ, Div. of Water. 3 pp.

Virginia Department of Environmental Quality. 1995b. General report of all waterbody data: Northwest River. 25 July 1995. VDEQ, Div. of Water. 3 pp.

Virginia Department of Environmental Quality. 2000a. General report of all waterbody data: North Landing River. VDEQ, Div. of Water. 3 pp.

Virginia Department of Environmental Quality. 2000b. General report of all waterbody data: Northwest River. VDEQ, Div. of Water. 3 pp.

Virginia Forestry Association. 1991. Social register of native big trees in Virginia. VAF, Richmond. 18 pp.

Walker, R. and L. Craighead. 1997. Analyzing wildlife movement corridors in Montana using GIS. Presented at 1997 ESRI Users Conference and published in conference proceedings. (http:www.grizzlybear.org/col/lcpcor.html) Sept. 2000.

Wall, G. 1997. Is ecotourism sustainable? Environmental Management 21(4): 483-491.

Ward, L. W., R. H. Bailey, and J. G. Carter. 1991. Pliocene and early Pleistocene stratigraphy, depositional history, and molluscan paleobiogeography of the coastal plain. Pages 274-289 in J. W. Horton, Jr. and V. A. Zullo, eds. Geology of the Carolinas. University of Tennessee Press, Knoxville.

Weldon Cooper Center for Public Service, Demographics, and Workforce Section. 2000. (http://www.virginia.edu/coopercenter/vastat/txt/est9099c.html) on-line version 1/21/00.

Weicher, J. C., and R. H. Zeibst. 1973. The externalities of neighborhood parks: An empirical investigation. Land Economics 49: 99-105

White, P. C. L. and J. C. Lovett. 1999. Public preferences and willingness-to-pay for nature conservation in the North York Moors National Park, UK. Journal of Environmental Management, 55:1-13.

Whitehead, D. R. and R. Q. Oaks. 1979. Developmental history of the Dismal Swamp. Pages 25-43 in P. W. Kirk, ed. The Great Dismal Swamp. Proc. of a symposium sponsored by Old Dominion

Univ. and United Virginia Bank-Seaboard National. The University Press of Virginia, Charlottesville.

Wieboldt, T. F., G. P. Fleming, J. C. Ludwig, and F. C. Huber. 1998. Noteworthy collections: Virginia. Castanea 63:82-91.

Wilson, S. 1993. Virginia Nonpoint Source Pollution Watershed Assessment Report. Department of Conservation and Recreation, Division of Soil and Water Conservation, Richmond, VA. 157 pp.

Wilson, A. M. and D. Lindenmayer. 1996. Wildlife corridors – their potential role in the conservation of biodiversity in rural Australia. Australian Journal of Soil and Water Conservation 9(2).

Woodward, S. L. and Hoffman, R. L. 1991. The nature of Virginia. Pages 23-50 in McDonald, J. N. and T. Skware, eds. Virginia=s endangered species: proceedings of a symposium, coord. by K. Terwilliger. The McDonald and Woodward Publishing Co., Blacksburg, Virginia.

Yahner, R. H. and C. G. Mahan. 1997. Behavioral considerations in fragmented landscapes. Conservation Biology 11(2): 569-570.

APPENDICES